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MINE SPOIL POTENTIALS FOR SOIL AND WATER QUALITY

West Virginia University

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The removal of coal from the earth by surface mining causes major disturbances to the environment. If environmental damages are to be minimized, it is essential that the extraction and reclamation processes be planned before mining occurs. This project has made major progress in developing techniques to pre-plan surface mining.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

ABSTRACT

Selected chemical, physical, and mineralogical measurements have been adapted to coal overburden sections of the Monongahela, Conemaugh, Allegheny, and New River formations of the Pennsylvanian in central and northern West Virginia.

Field studies, core logging, simulated weathering, and laboratory measurements provide a basis for recognizing toxic (pH below 4.0) or potentially toxic (reduced sulphur sufficient for mineral acid in excess of neutralization capacity) rock or soil as well as superior materials (pH near neutral and high available phosphorus) for topsoiling mined lands.

Laboratory measurements have been keyed to regional trends of coal and rock types within the northern Appalachian coal basin, confirming the validity of the three previously suggested Surface Mining Provinces and providing a basis for useful extrapolation of results beyond sampled sites.

Improved classification of minesoils within the comprehensive American system, Soil Taxonomy, based on consistently observable properties of minesoil profiles, provides the needed basis for more precise management, including liming, accurate fertilization, and more satisfactory growth of plant combinations emphasizing legumes or repeated nitrogen fertilization.

This report was submitted in fulfillment of Project S 800745 by West Virginia University under the sponsorship of the Environmental Protection Agency. Work was completed as of November, 1973.

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- Geologic Considerations (Arkle, Grube, and Lotz)
- Soil Considerations (Sencindiver and Smith)
- Methods Adapted to Minesoils (Ali, Ammons, Freeman, Grube, Hidalgo, Jencks, Renton, Singh, Smith, Sobek and Sturm)
- Acid Producing Potential and Neutralizing Potential (Arkle, Grube, and Smith)
- Chemistry and Mineralogy of Overburden Profiles (Ali, Grube, Singh and Smith)
- Petrographic Investigation of Sandstone Weathering (Arnold and Heald)
- Laboratory Weathering Studies (Ali, Grube and Sobek)
- Characterization of Mine Wastes (Freeman, Grube and Smith)
- Evidence from Old Minesoils (Ammons, Sobek, Smith and Sturm)
- Minesoil Interactions with Plant Covers and Management (Ammons, Smith and Sturm)

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SECTION I

CONCLUSIONS

1. Successful pollution control and land-use planning for surface mining depend upon choice of measurements and creation of systems that fit local conditions.

2. Logging of test cores and high walls can now be used by any experienced person to make distinctions needed that convey useful information about minesoil to help achieve environmental objectives. Standard criteria include: (1) rock color by comparison with Munsell color charts; (2) rock hardness compared to fingernail or knife; (3) rock streak on white streak plate; (4) rock grittiness (sandiness) or smoothness; (5) rock splitting tendency into thin layers; (6) rock layering alternation (interlayering); (7) rock fizzing in dilute hydrochloric acid.

3. The acid-base accounting method is a useful means of rating coal overburden materials for proper placement in surface minespoils, to assure favorable and productive materials for anticipated uses of minesoils.

4. Toxic or potentially toxic coal overburden associated with acidity may be defined satisfactorily for many purposes by three measurements: (1) pH of the pulverized rock slurry in distilled water; (2) total or pyritic sulphur; (3) neutralization potential against hydrochloric acid. The methods and calculations required are described in detail under "Methods Adapted to Minesoils" (Section VI).

5. Field and laboratory measurements indicate that the rate of formation of sulphates from pyritic sulphur is reduced substantially by raising the pH of acid minesoils by liming. Presumably, the reduced rate results from reduced activity of the chemoautotrophic bacteria involved, even though chemical oxidation processes continue.

6. Plant-available phosphorus extraction with a buffered sodium bicarbonate solution is better adapted to the wide range of pH and associated chemical conditions in minesoils than acid extraction methods, and should be used to improve the accuracy of recommendations for phosphorus fertilization.

7. Topsoiling materials for use on minesoils are readily classified into three kinds: (1) Synthetic topsoils; (2) Weathered topsoils (free of pyritic acid because of natural weathering; and (3) Geologic topsoil (favorable because of natural basic materials and plant nutrients deposited geologically). Synthetic materials are used primarily as mulches to aid quick establishment of ground covers.

8. Recent studies of old sandstone minesoils confirm that low pH and plant nutrient levels are prime causes of persistent lack of volunteer vegetation, although low water-holding capacities may limit growth rates and yields. Very little plant invasion occurs at pH below 4.0 and with very low available phosphorus. In general, the relative requirements of invading tolerant plants in vegetated versus barren areas were: redtop > black birch > deertongue > broom sedge > poverty grass (Danthonia spicata) > red maple > barren. Moderate liming and fertilization should assure total revegetation since plants are growing wherever pH and nutrient levels are only slightly higher than barren.

9. Petrographic (microscopic study of thin sections) observations, gentle laboratory dispersion in Calgon, and field observations agree that sandstones represented in the Coal Measures are variable in inherent strength or stability and the percentage of fines for soil formation is likely to provide important soil differences at different locations. Methods of observation and testing are being perfected to predict soil textures as well as chemical properties of minesoils.

10. Adaptation of other laboratory methods to fresh overburden materials or to old spoils include the following: (1) carbon, by two methods; (2) cation exchange capacity by 5 methods; (3) available phosphorus by 3 methods; (4) "lime requirement" by 4 methods; (5) sulphate removal by solution; (6) potassium, calcium and magnesium by acid extraction and atomic adsorption measurement; (7) exchangeable aluminum by neutral salt extraction and atomic adsorption measurement; (8) particle sizes by screening, gentle, prolonged shaking in Calgon solution and sedimentation; (9) moisture retention against variable pressure potentials; (10) mineral identification in thin sections and in

grain mounts by optical (petrographic) methods; (11) mineral identification by x-ray diffraction by oriented slides; (12) mineral identification by differential thermal analysis.

11. This report expands and confirms previous findings regarding the pyrite-free weathered zone approximating 20 feet of depth below the land surface in Lower Mahoning sandstone over Upper Freeport coal and in Saltsburg sandstone over the Bakerstown coal where the Saltsburg is not replaced by mudrocks. In one case (Site B-B' 1 Whitman Flats) the sandstone over Kittanning coal retained its low chroma and pyritic acid potential almost to the soil surface.

12. Surface Mining Province #3, typified by the Pittsburgh-Redstone interval, contains an abundance of neutralizing material in calcareous mudrocks and limestones for burying all toxic or potentially toxic horizons.

13. The geologic section within Surface Mining Province #3, from northcentral Barbour County on the northeast to the environs of Glenville on the southwest shows limits of Pittsburgh and Redstone coal both eastward and westward from the central basin and helps explain coal production in Braxton, Gilmer, Lewis, Upshur, Barbour, Harrison and Taylor counties.

14. Chemical and physical analyses of overburden materials from locations extending from the center to the peripheral areas of the major coal basin (Pittsburgh and Redstone seams) confirm observed changes in overburden composition associated with location within the depositional basin. These changes include thinning of limestone beds coincident with thinning of the coal toward the edges of the basin, encroachment of "red beds" of calcareous dusky red mudstone from outside areas toward the coal basin proper, and zones of pyritic, potentially acid-forming, channel sandstones associated with localized areas of high sulfur coal.

15. Kittanning coals of the Allegheny Formation (Surface Mining Province #2) involve overburdens that contain less neutralizing potential than overburdens in Province #3. This confirms the validity of placing Kittanning intervals in Province #2, together with Freeport and associated coals. Careful selection of near-neutral or carbonate containing mudrocks may be necessary in order to bury all potentially toxic overburden and assure favorable topsoil. However, in all cases studied it is possible to assure favorable soil for reclamation and use, and some of the best minesoil and reclamation in the State occurs on properly managed Lower Kittanning overburden near Brandonville, Preston County.

SECTION II

RECOMMENDATIONS

1. Surface miners working in the Pittsburgh-Redstone interval of Surface Mining Province #3 should leave only selected neutral or slightly alkaline mudrock in the surface foot of the graded spoil. In most cases this material will fizz in dilute hydrochloric (muriatic) acid (Sections IV and VII).

2. Surface miners of Kittanning coals of Surface Mining Province #2 should select overburden for placement in the surface foot of graded spoil which meets the requirement of being neither toxic nor potentially toxic by simplified standards that we have developed (Sections IV and VII).

3. Overburden associated with the Bakerstown and Brush Creek coals should be considered marginal between Surface Mining Provinces #2 and #3. Sufficient favorable mudrock (or shale) should be selected from the overburden to assure burial of all potentially toxic material as well as unusable cobbles and boulders that are often found on the original land surface (Sections IV and VII).

4. Although the Sewell coal overburden, Surface Mining Province #1, where studied in northern Greenbrier County, is very low in total sulphur and is neither toxic nor potentially toxic, surface miners should select mudrocks or shales for placement in the surface foot of graded spoil which will weather quickly enough to assure at least 50% fines (less than 2 mm diameter) for favorable soil water relations. Different relationships may exist elsewhere in the Sewell coal field (Sections IV and VII).

5. Surface miners should learn to distinguish consistently between black materials that are high in organic carbon and those that appear black for other reasons. In general, rocks that give a very dark streak or powder (i.e. Munsell color value of three or less) are high in carbon (greater than 20%) and are likely to be toxic, whereas some shales, mudrocks and limestone

which appear black but which give a light streak or powder have no potential for toxicity (Section VII).

6. Surface miners should study their coal overburden in advance so as to plan for more efficient handling and placement.

7. At least three laboratory measurements should be made of overburden if acidity is a potential problem. These are: (1) pH of pulverized rock slurry in distilled water; (2) total or pyritic sulphur; and (3) neutralization potential against a strong acid (Section VII).

8. In reclaiming acid minesoils emphasis should be placed on working pulverized limestone into the top 3 to 6 inches of graded spoil well in advance of fertilizing and seeding (Section XIII).

9. Greater emphasis should be placed on use of plant nutrient tests that are appropriate for the nature of the minesoils. For example, phosphorus extraction with buffered sodium bicarbonate should give more reliable results than acid extractions with many minesoils (Section VIII).

10. Greater emphasis should be placed on establishment of legumes even though such emphasis may require thinner stands of grass and slower initial groundcover (Sections XII and XIII).

11. More attention should be given to the rate of physical weathering of overburden and the final particle sizes and water-holding capacities to be expected from different rock horizons.

12. Surface miners should encourage the classification and mapping of minesoils within the comprehensive system used by the U.S. Dept. of Agriculture and State Agricultural Experiment Stations and other agencies. This will aid reclamation and proper use of minesoils as important natural resources the same as other soils (Section V).

13. Topsoiling should involve careful selection of the best available material for placement on the land surface. In some instances the best material may be geologic material occurring below the weathered zone in the overburden section (Sections VII and VIII).

14. If legal restrictions permit, many high walls should be used as an aid to creation of desirable, gently sloping land and to help prevent excessively long erodible slopes that contribute to downstream sedimentation.

15. Pre-pedologic studies of soil parent materials (including coal overburdens) should be continued until we can assure that placement, treatment, and continuing management will produce consistently predictable results for anticipated agricultural, forestry, engineering and recreational uses of minesoils.

SECTION III

INTRODUCTION

This study was conducted in order to obtain information necessary to guide surface mining operations and mine spoil reclamation on rapidly expanding acreages in northern and central West Virginia. Considerable geologic and soils information is available regarding rock sections above the coals in this area, but use of this information requires proper identification of position in the section as well as interpretations of behavior when previously buried rocks are exposed to surface or near surface environments. Moreover, the qualities of many rocks are not known in terms of influence on soil formation and water quality.

This report expands information developed and reported as EPA Project 14010 EJE 12/71, "Mine Spoil Potentials for Water Quality and Controlled Erosion", and extends these findings to other coal overburden materials and neighborhoods of active or planned surface mining. Improved methods of characterizing coal overburden and minesoil materials according to suitability for placement in the spoil should lead to improved or more economical methods of preventing water pollution from minesoils and mine wastes and increase success of vegetation and planned land use.

The following objectives were fulfilled in order to develop sufficient information to assure that variable earth materials in surface mine spoils and mine wastes were placed and treated appropriately for prevention of water pollution and development of desirable soils and landscapes: (1) identification, correlation, description, and analysis of soil and rock strata in regions where surface mining is in progress or planned; (2) determination of chemical, physical, and mineralogical properties of soil, rock, mine spoil, and mine waste samples involved in water quality problems; (3) determination of natural or induced weathering processes and rates for earth materials in known or controlled environments; (4) determination of interactions among spoils, amendments, plants, and water over both short and long time intervals.

In addition to new information regarding properties of the coal overburden and mine waste materials discovered during this work, the coworkers in these studies, providing interrelated competence in geology, soils, chemistry, plant science, and general conservation, have been able to develop new technology or adapt existing methodology to quantify chemical and physical parameters that are most meaningful in understanding the problems of preventing water pollution and maintaining desirable plant growth on these materials.

SECTION IV

GEOLOGICAL CONSIDERATIONS

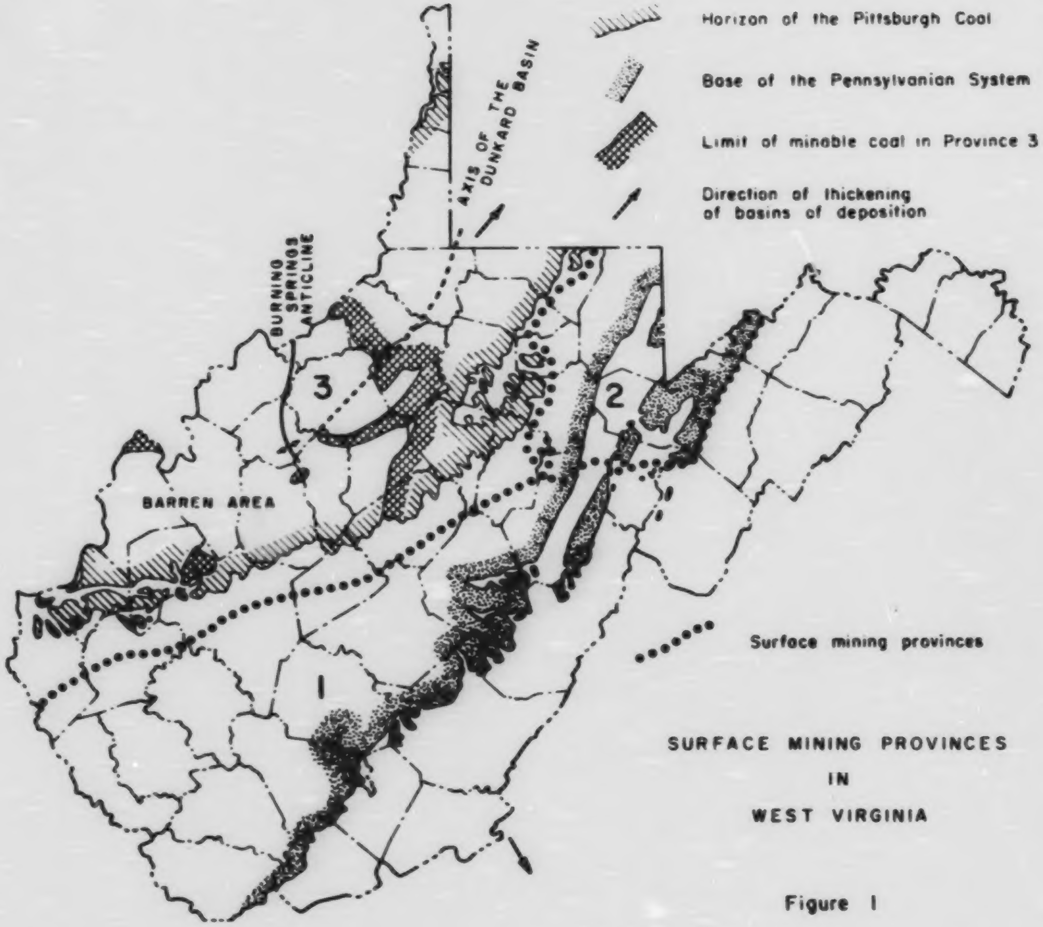
INTRODUCTION

The following discussion and illustrations review the geological approach used in the methodical study of coal overburdens and mine spoils in Surface Mining Provinces 1, 2 and 3 of West Virginia (Figure 1) as defined in the report Mine Spoil Potentials for Water Quality and Controlled Erosion (West Virginia University, 1971_a p. 12-18).

Geologic studies under EPA Project S 800745, 1971-1973, were conducted in Gilmer, Lewis, Upshur, Barbour, Harrison and Taylor counties (Surface Mining Province 3); Preston, Mineral, Grant, Tucker, Randolph and Barbour (Surface Mining Provinces 2 and 3); and Greenbrier (Surface Mining Province 1) counties, West Virginia.

The illustrations in areas of principal study in this report depict the characteristic associations of beds in Surface Mining Province 3 (geologic cross section A-A' representing an area of some 800 square miles) (Figures 4, 5, 6, and 7) of Gilmer, Lewis, Upshur, Barbour, Harrison and Taylor counties and in Surface Mining Province 2 (geologic cross sections B-B' and C-C' representing an area of over 600 square miles and D-D') (Figures 4, 5, 8, 9, 10 and 11) and correlative beds of Surface Mining Province 3 generally high in the hills of Randolph, Barbour, Preston, and Tucker counties, West Virginia. Work has been conducted in smaller areas of Mineral, Grant and Greenbrier counties, West Virginia (Figure 4).

The delineation of Surface Mining Provinces in West Virginia is based on the gross physical and chemical characteristics of thick sections of rocks and associated coals and physiographic development of large areas which reflect the depositional history and the general geology of coal-bearing rocks of West Virginia.


Horizon of the Pittsburgh Coal
Base of the Pennsylvanian System
Limit of minable coal in Province 3
Direction of thickening of basins of deposition
Surface mining provinces
AXIS OF THE DUNKARD BASIN
BURNING SPRINGS ANTICLINE
BARREN AREA
1
2
3

SURFACE MINING PROVINCES
IN
WEST VIRGINIA

Figure 1

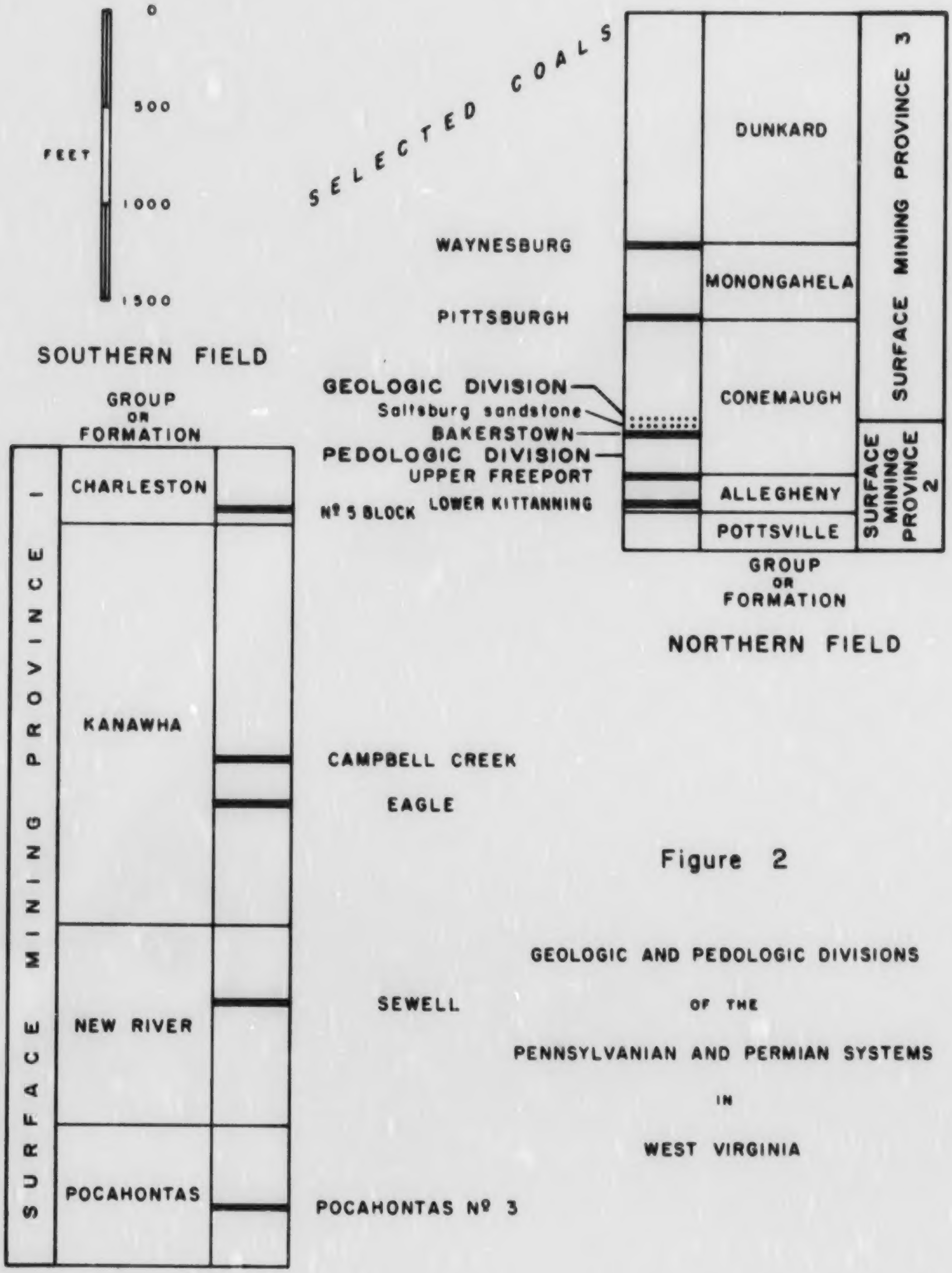


Figure 2

GEOLOGIC AND PEDOLOGIC DIVISIONS
OF THE
PENNSYLVANIAN AND PERMIAN SYSTEMS
IN
WEST VIRGINIA

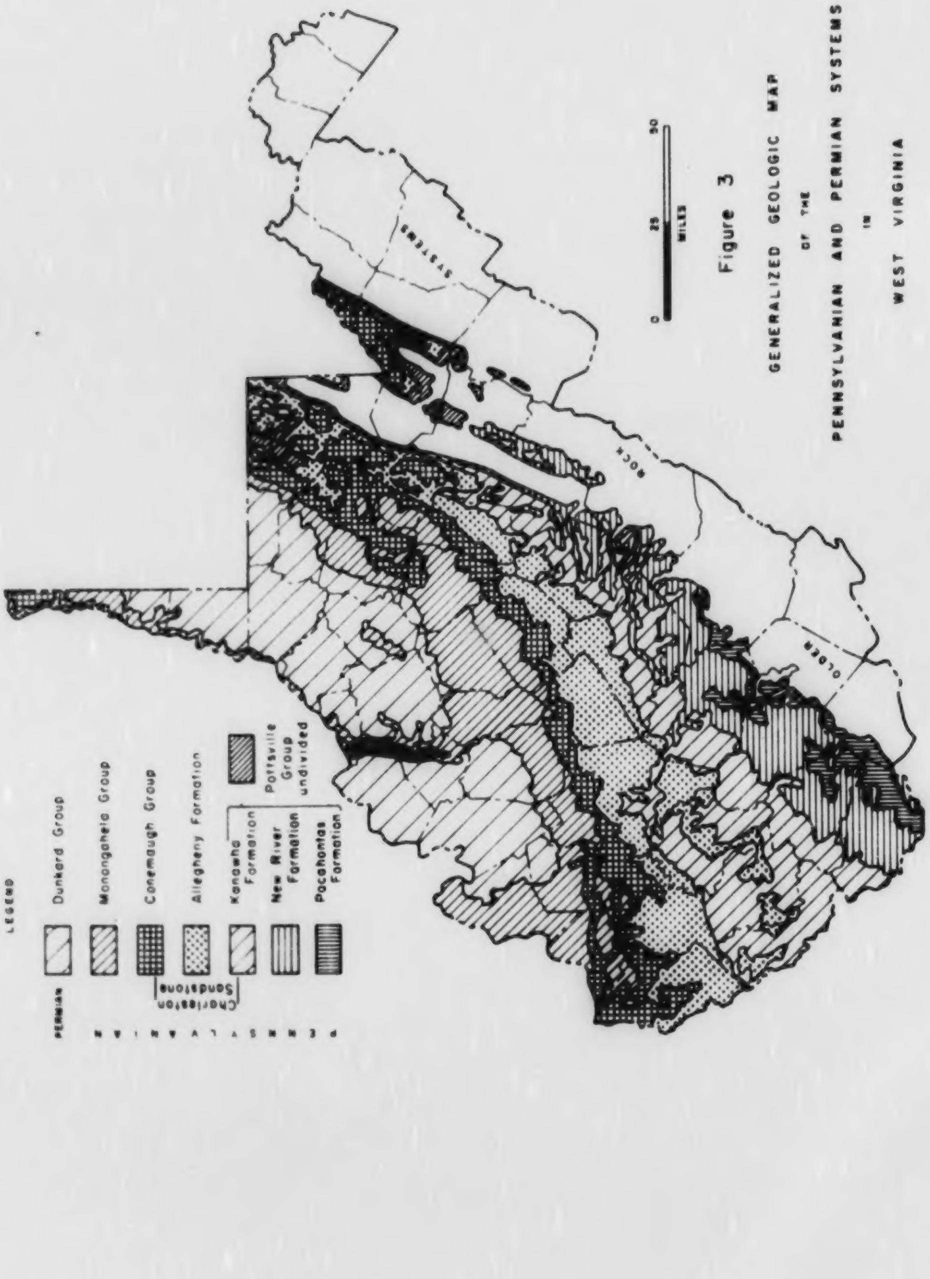


Figure 3

GENERALIZED GEOLOGIC MAP OF THE PENNSYLVANIAN AND PERMIAN SYSTEMS IN WEST VIRGINIA

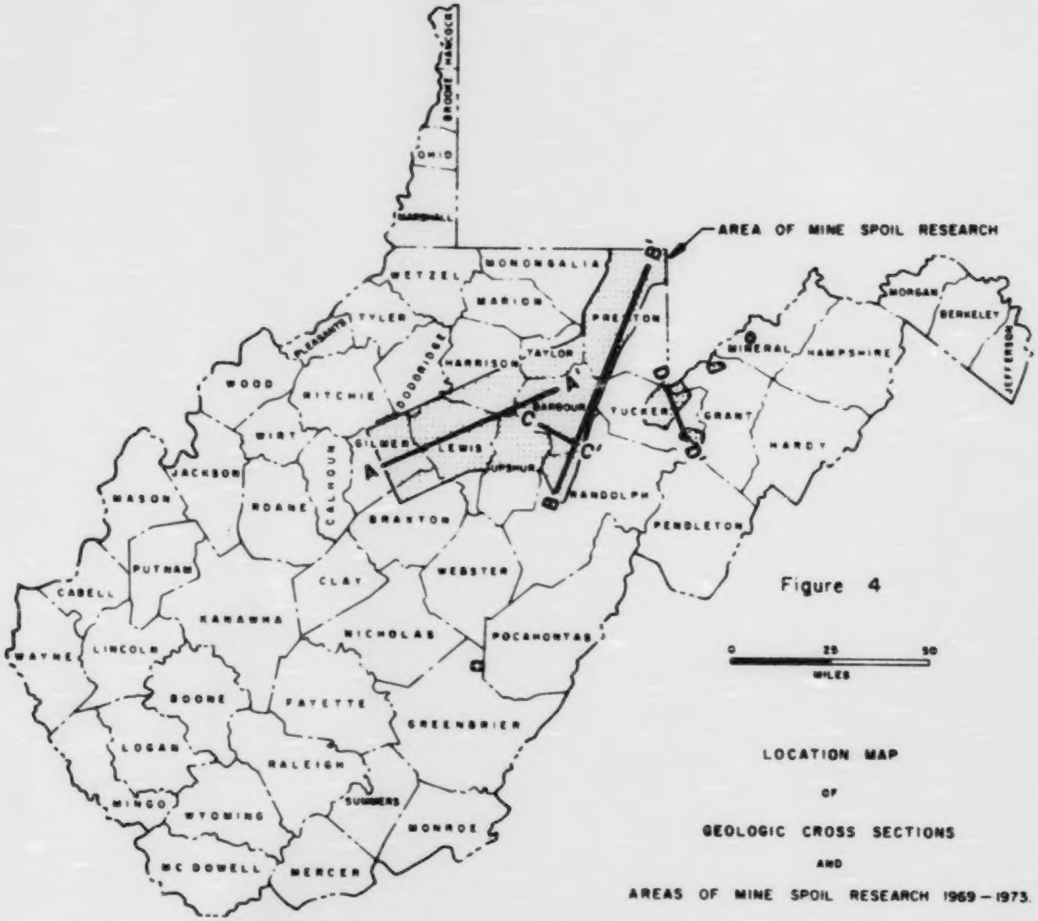


Figure 4

LOCATION MAP

OF

GEOLOGIC CROSS SECTIONS

AND

AREAS OF MINE SPOIL RESEARCH 1969 – 1973.

LEGEND

GEOLOGIC CROSS SECTIONS A-A', B-B', C-C' and D-D'

(Figures 7, 9, 10 and 11)

Lithologies adapted to the
American Comprehensive System
of Soil Classification

Figure 5

▒ Sandstone

□ Shale and siltstone

▨ Mudstone (includes claystone and flint and plastic clay)

r Red shale and mudstone and variegated or mottled red and green and gray shale, mudstone and claystone

▦ Limestone (includes beds and carbonate knots, nodules, concretions and pellets)

═ Coal and partings

═ 5'-0" Thickness of coal section

Marine fossil

Fresh water fossil

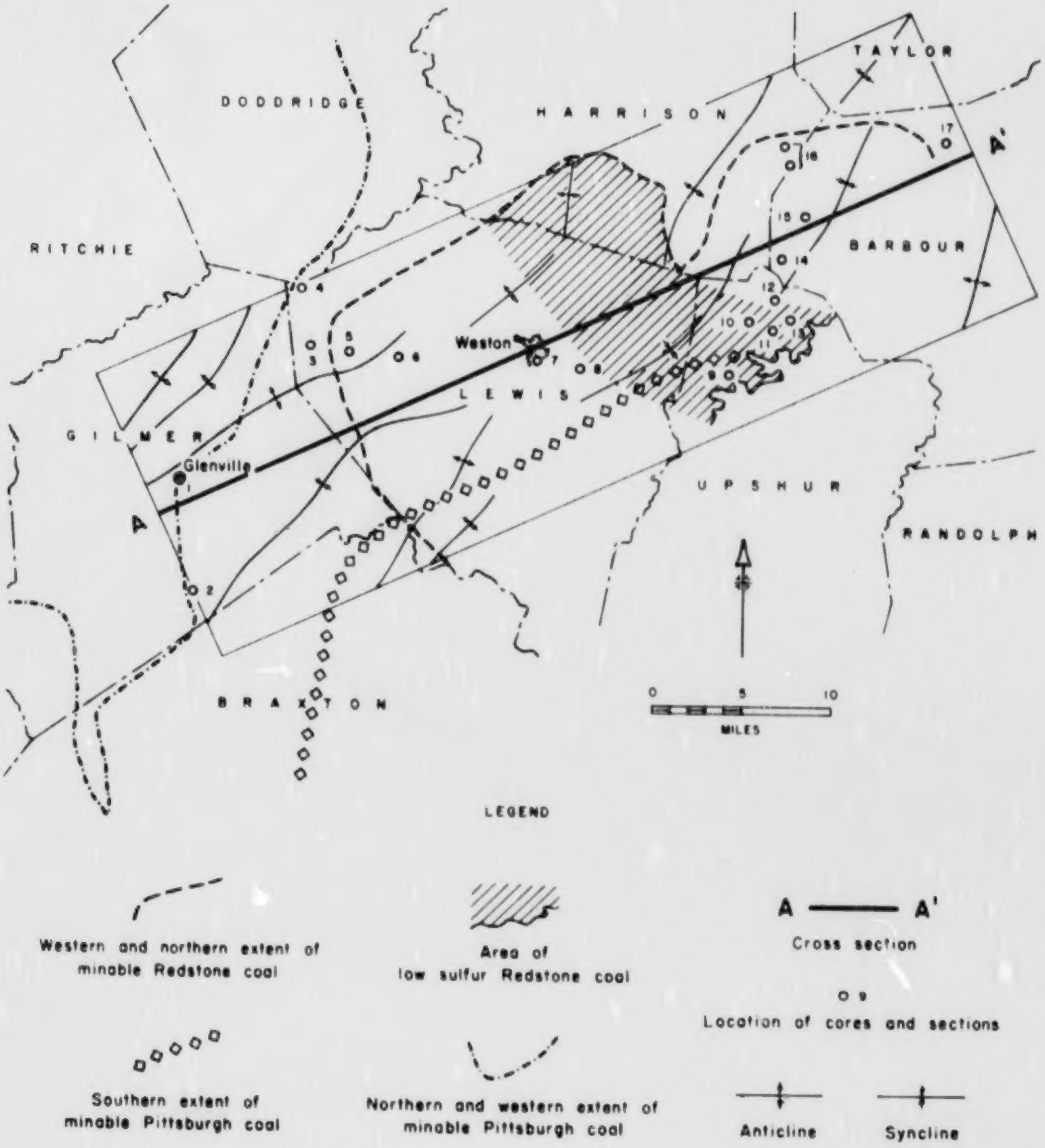

DODDRIDGE
HARRISON
TAYLOR
RITCHIE
BARBOUR
Weston
LEWIS
GILMER
Glenville
UPSHUR
RANDOLPH
BRAXTON
A
A'
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
0
5
10
MILES
LEGEND
Western and northern extent of minable Redstone coal
Area of low sulfur Redstone coal
A — A'
Cross section
○ 9
Location of cores and sections
Southern extent of minable Pittsburgh coal
Northern and western extent of minable Pittsburgh coal
Anticline
Syncline

Figure 6

AREA OF STUDY ADJACENT TO CROSS SECTION A - A'
AND MINABLE EXTENT OF PITTSBURGH AND REDSTONE COALS

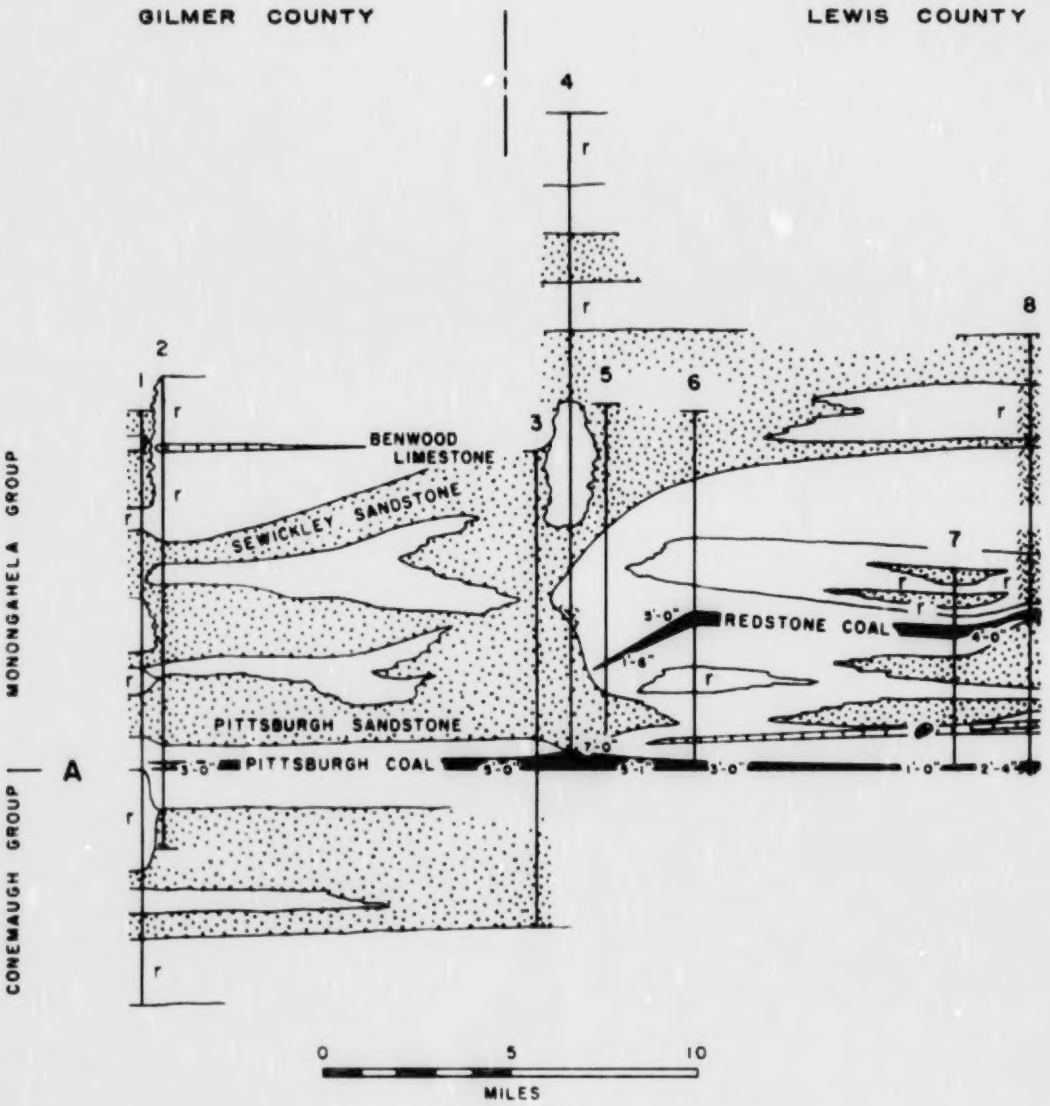
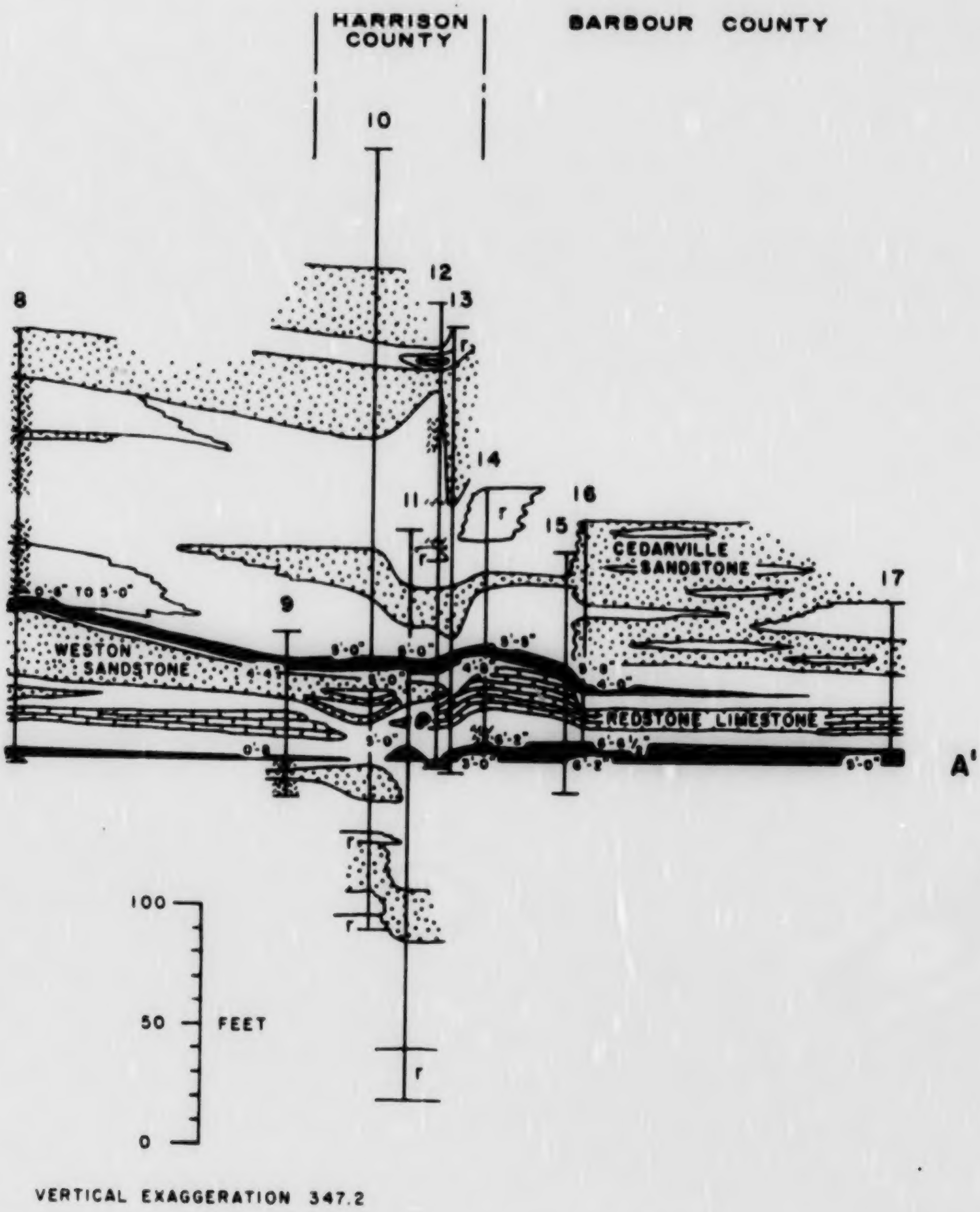


Figure 7

GEOLOGIC CROSS SECTION A-A'


HARRISON COUNTY
BARBOUR COUNTY
10
12
13
8
14
11
16
15
17
9
r
CEDARVILLE SANDSTONE
WESTON SANDSTONE
REDSTONE LIMESTONE
A'
100
50
0
FEET
VERTICAL EXAGGERATION 347.2

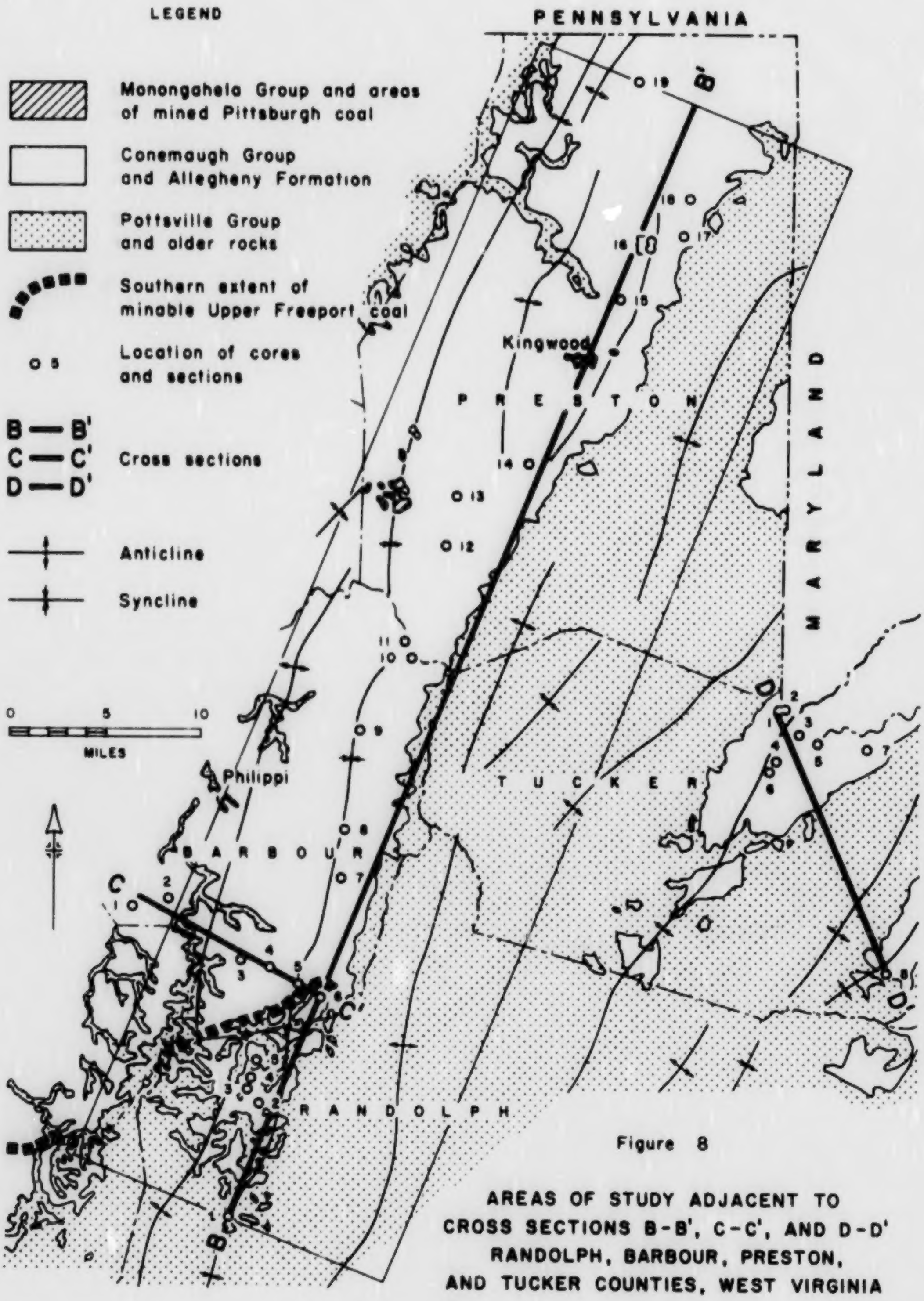

LEGEND
Monongahela Group and areas of mined Pittsburgh coal
Conemaugh Group and Allegheny Formation
Pottsville Group and older rocks
Southern extent of minable Upper Freeport coal
Location of cores and sections
o 5
B — B'
C — C'
D — D'
Cross sections
Anticline
Syncline
0 5 10
MILES
PENNSYLVANIA
MARYLAND
PRESTON
TUCKER
BARBOUR
RANDOLPH
Kingwood
Philippi
B
B'
C
C'
D
D'

Figure 8

AREAS OF STUDY ADJACENT TO CROSS SECTIONS B-B', C-C', AND D-D' RANDOLPH, BARBOUR, PRESTON, AND TUCKER COUNTIES, WEST VIRGINIA

A joint geologic and pedologic study in two large areas of Surface Mining Provinces 2 and 3 not only tests the geological assumption but refines knowledge of the ultimate potential of spoil materials (principally rock) in the pedogenic processes in areas presently undergoing extensive surface mining (Figures 39 to 49). In addition, it is anticipated that the coal economy of these counties will increasingly rely on the extraction of coal by surface methods in the future.

Figures 39 to 49 (West Virginia Department of Mines, 1945-1971) in Appendix A illustrate the trends in production and methods of extraction of the various seams of coal since 1945 in the counties of principal study. All counties with the exception of Lewis from which little coal has been produced by underground methods and Harrison County have shown a marked decline in production of coal by underground methods in recent years. During World War II and the immediate post war years, Harrison County led other counties of West Virginia in the extraction of coal by surface methods. In addition, three of the large underground mines in Harrison County were closed during 1972 (Arkle and Barlow, 1972, p. 24). The importance of surface mining to coal economies of Lewis, Upshur, Barbour, Randolph, Tucker, and Preston counties is recorded on the bottom diagram of Figures 42, 44, 45, 47, 48, and 49 respectively.

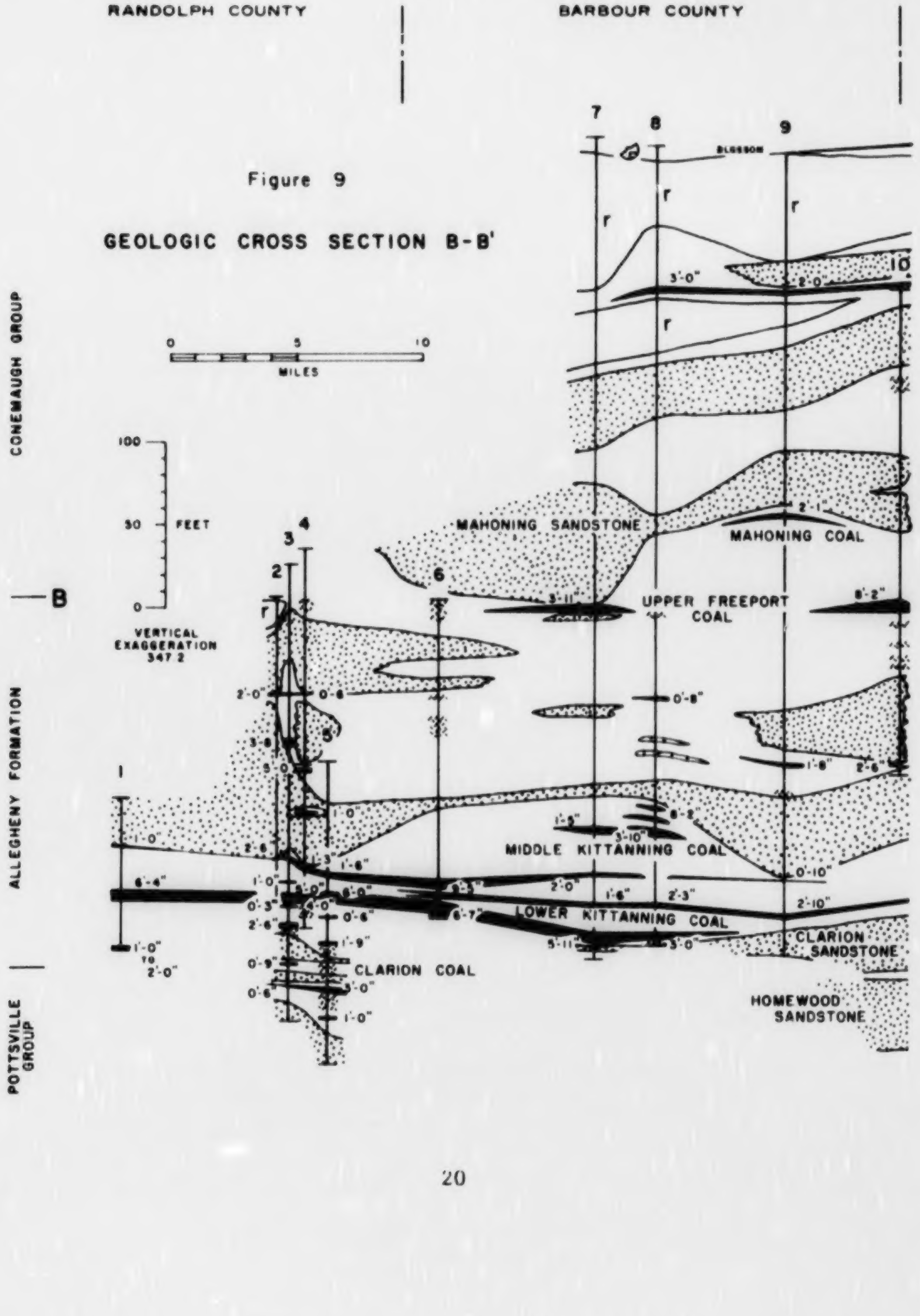
Figure 39 compares the year to year trend in coal production in Barbour County with adjacent counties and Figure 45 depicts the history of mining in Barbour County since 1945. The upper diagram shows the percentage of annual production of the various seams by mining methods, i.e., underground mining versus surface mining. Three coals, the Pittsburgh, Redstone and Lower Kittanning in order of importance, are the principal seams of Barbour County. The lower diagram shows the annual percentage of West Virginia coal production and the tonnage of coal produced by underground and surface methods annually in Barbour County. In 1947, Barbour County produced 2.5 percent of the State's total; in 1971 over 3.0 percent.

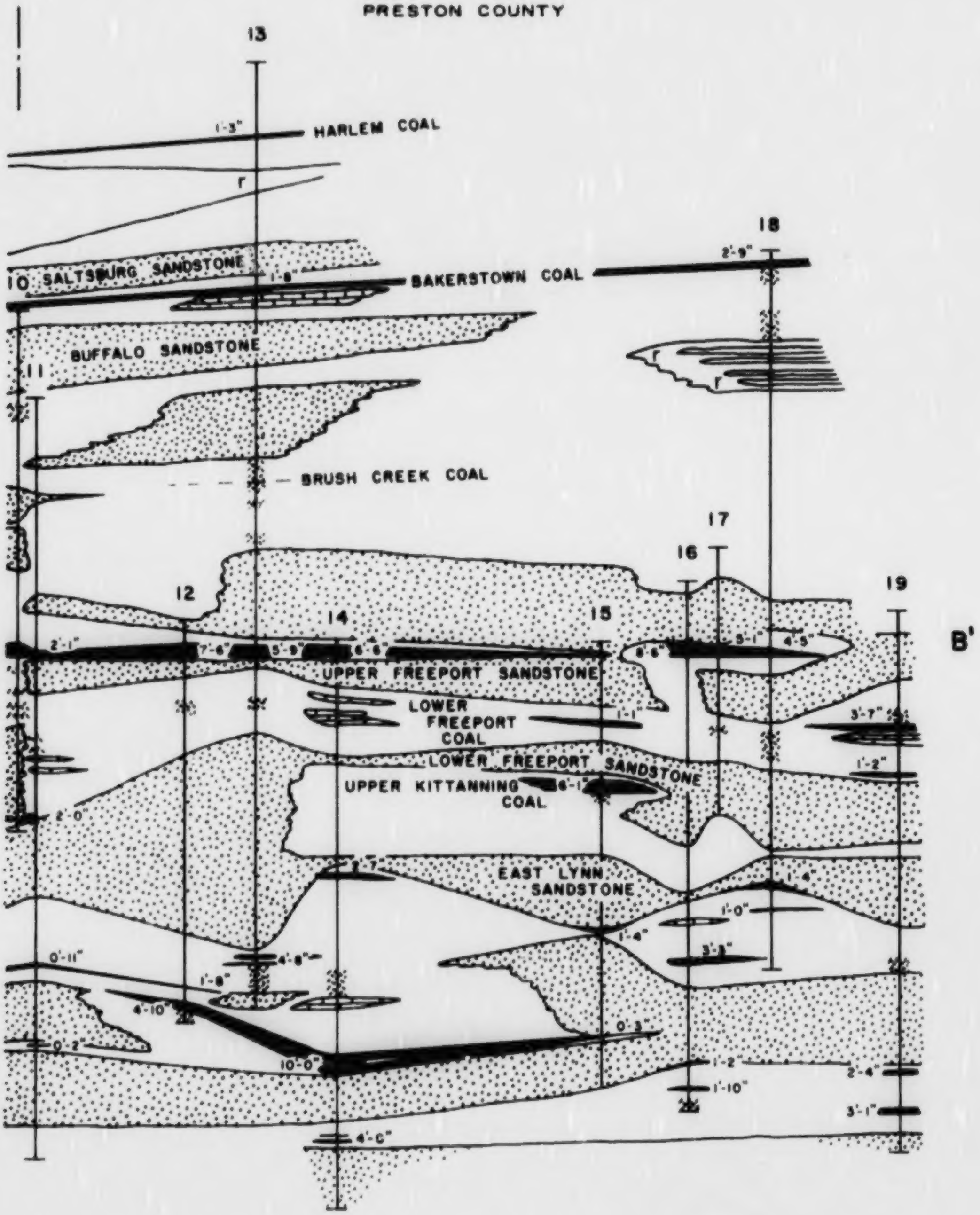
Barbour County reached a peak in coal production of 2,965,498 tons by underground extraction in 1925, however the largest production of 3,984,689 tons was attained with both underground and surface extraction in 1947. As the underground reserves of Pittsburgh coal were depleted principally in the Elk Creek drainage in 1955, some of the large operators shifted exploration and development to the Lower Kittanning coal in the environs of earlier mining activity near Philippi as indicated in the upper diagram (Figure 45).

Surface mining commenced in Barbour County in 1943 during World War II and has grown with increasing tempo to the present time. In recent

Figure 9

GEOLOGIC CROSS SECTION B-B'




PRESTON COUNTY
13
1'-3"
HARLEM COAL
r
10
SALTSBURG SANDSTONE
1'-8"
BAKERSTOWN COAL
18
2'-9"
r
r
BUFFALO SANDSTONE
11
BRUSH CREEK COAL
17
16
12
14
15
19
B'
2'-1"
7'-6"
5'-9"
6'-6"
8'-6"
5'-1"
4'-5"
UPPER FREEPORT SANDSTONE
LOWER
FREEPORT
COAL
1'-1"
3'-7"
LOWER FREEPORT SANDSTONE
1'-2"
UPPER KITTANNING
COAL
6'-1"
2'-0"
2'-7"
EAST LYNN
SANDSTONE
1'-4"
1'-0"
1'-4"
3'-1"
0'-11"
4'-8"
1'-8"
4'-10"
0'-2"
10'-0"
0'-3"
1'-2"
1'-10"
2'-4"
3'-1"
4'-0"

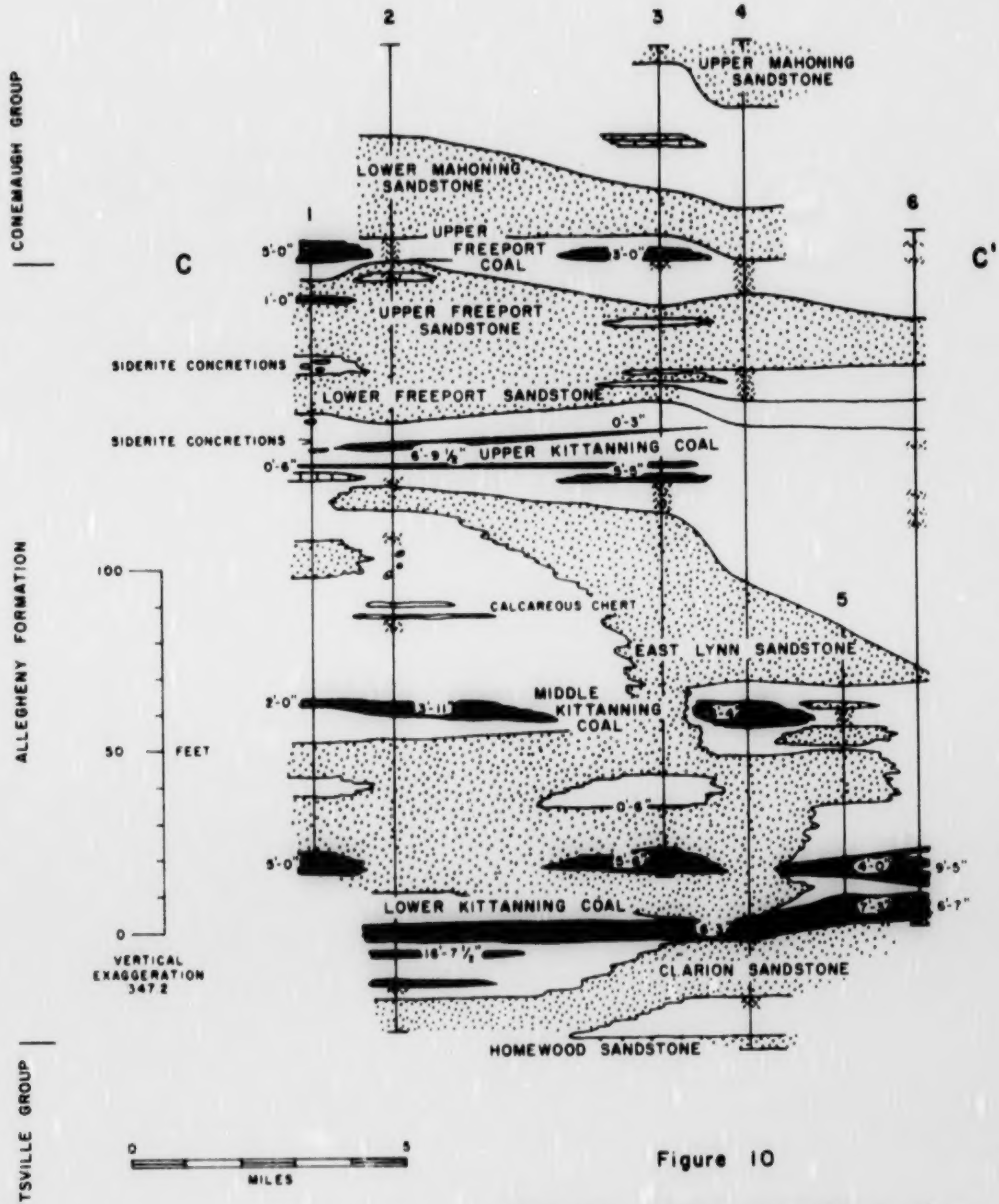


Figure 10

GEOLOGIC CROSS SECTION C-C'

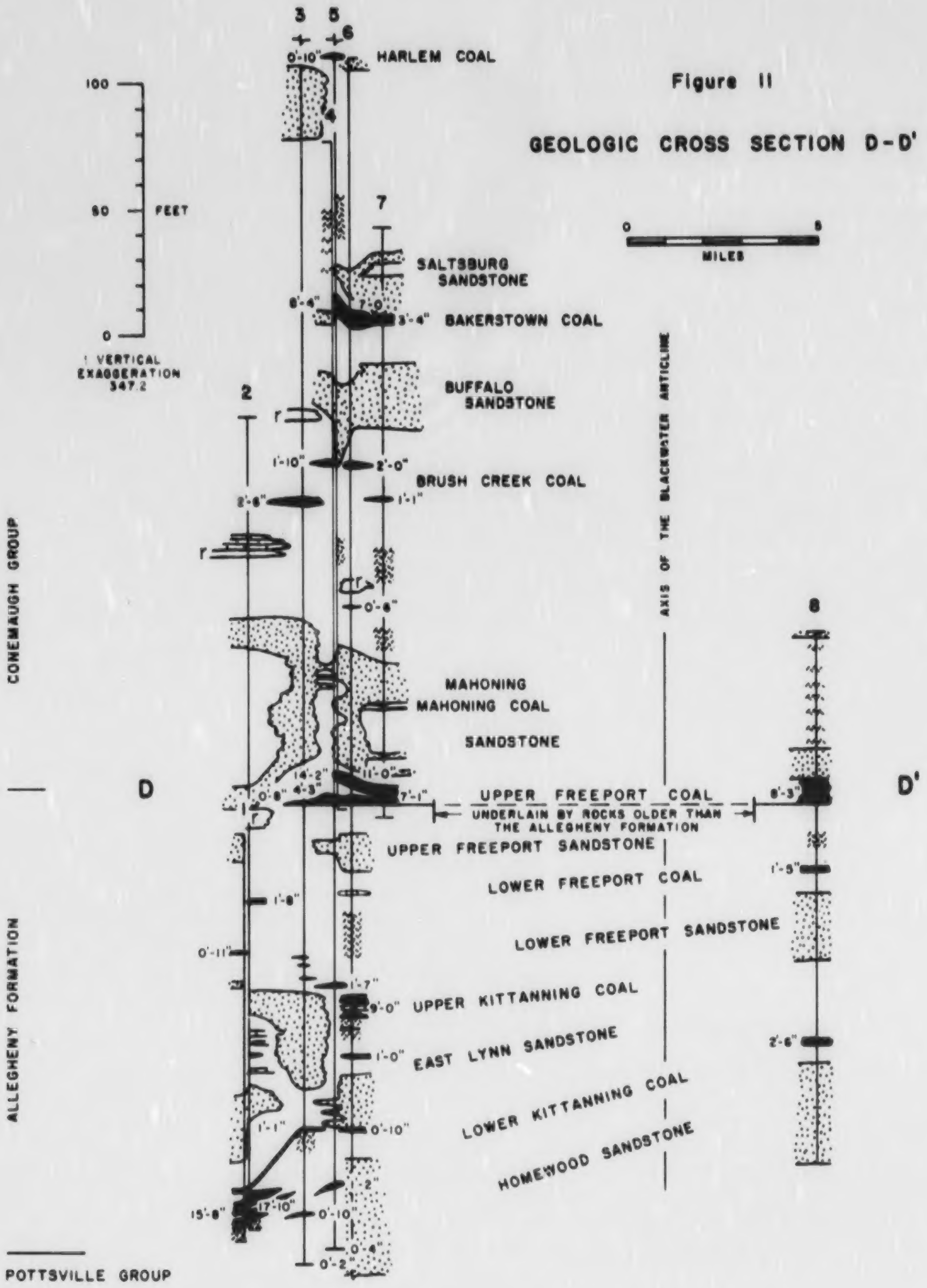


Figure 11

GEOLOGIC CROSS SECTION D-D'

years, large amounts of capital have been invested to improve the efficiency of extraction of surface exposures on croplines of the depleted underground reserves of Pittsburgh coal and the thinner nearly solid Redstone coal some 30 feet higher in the section (Figure 7) on the Elk Creek drainage. In 1972, Barbour County ranked 2nd, surpassed only by Kanawha County, in the production of coal by surface methods in West Virginia.

SURFACE MINING PROVINCES

The Pennsylvanian and Permian Systems of West Virginia can be divided into three surface mining provinces (Figure 1) on generalizations of the physiographic, stratigraphic and structural geology of the State.

These generalizations are complicated regionally away from the areas of principal swamp environments by the encroachment of clastic sediments. These areas are generally outside the scope of this study. This relationship is clearly illustrated in the southwestern extremities of cross section A-A' (Figure 7). Surface Mining Province 1 includes beds of an older rapidly subsiding coal basin in southern counties of West Virginia and Surface Mining Provinces 2 and 3 includes beds of a younger more stable basin in northern and western West Virginia. A buffer section, essentially of clastic sediments, separates the two areas of principal coal production in West Virginia. These assumptions are confirmed by regional synthesis of the orientation, distribution, and concentration of the clastic sediments with respect to swamp, lacustrine, and marine environments of deposition (Figures 6 to 11).

The division between Surface Mining Provinces 2 and 3 is transitional. It is arbitrarily placed on the Saltsburg sandstone for geologic reasons. The pedologic study of the overburden of the underlying Bakerstown and Brush Creek coals, mined locally by surface methods in Preston, Barbour, Tucker, Grant and Mineral Counties, West Virginia and Garrett and Allegheny counties, Maryland, dictates that the pedologic division between Surface Mining Provinces 2 and 3 be lowered over 100 feet in the section to the overburden above the Mahoning (local) or Upper Freeport coals, whichever is present (Figure 2).

These generalizations are further complicated within the principal areas of coal production by the diverse nature of the depositional history of at least 6150 feet (1880 meters) of rocks of Pennsylvanian and Permian age in West Virginia. Streams and distributaries of the shifting drainage system cut channels across the coal swamp and deposited clastic sediments. In addition, differential compaction of the sediments below the swamp floor disrupted the continuity of the physical and chemical characteristics of the swamp. The nature of these disruptions of swamp formation is evident in the variability in thickness of coals, particularly in Surface Mining Province 2 (Figures 8-11).

The physiography of Surface Mining Province 1 is characterized by steep slopes extending from narrow winding valleys to inaccessible and rugged ridges ranging in relief from 600 feet (180 meters) in the Charleston area, Kanawha County to as much as 1400 feet (420 meters) farther east in the New River Gorge, Fayette County.

Multilevel mining of numerous seams of coal is confined to Mercer, McDowell, Wyoming, Mingo, Logan, Raleigh, Boone, Kanawha, Fayette, Nicholas and Greenbrier counties, West Virginia. Similar thin, less numerous coals are produced in a small way in Randolph, Webster and Pocahontas counties and are of marginal importance in Wayne, Lincoln and Clay counties. Pocahontas and Lincoln counties are included in a legislative moratorium, recently extended until 1975, on surface mining in 22 counties of West Virginia.

The beds of the Pocahontas, New River, and Kanawha Formations and Charleston Group, in ascending the section, represent the earlier of the two coal basins of Pennsylvanian age in West Virginia (Figure 2). The basin subsided intermittently and deepened to the southeast. The sediments, essentially a wedge of fine to coarse clastic sediments, were derived from older rocks of the Appalachian region to the south. The coal bearing facies, the base of which is the southeastern exposure of Pennsylvanian rocks in southern West Virginia and western Virginia, thins rapidly from the thickest section to the northwest into massive marine (early) and deltaic (late) sandstones and finally disappears in the subsurface of western West Virginia. The rate of thinning is about 20 feet per mile (3.5 meters per kilometer) to the northwest.

Interestingly, the older coals, exposed on the southeast, are semi-bituminous high carbon and low sulfur coals with volatile matter ranging from 13 to 18 percent. The volatile matter increases to greater than 34 percent with a commensurate decrease in carbon content and increase in average sulphur content to 1.50 percent in ascending the section to the northwest in the direction of maximum development of the youngest coals of Surface Mining Province 1. The northwestern boundary of Surface Mining Province 1, drawn on the 1.50 sulfur line of composite unweighted coal analyses (C. W. Lotz, Jr., 1970, oral communication) nearly coincides with the boundary derived from geological considerations (Arkle, 1969 p. 62). It is along this line that commercial coals of the older coal field of West Virginia disappear in the northwest thinning of the section.

The rocks associated with coal in Surface Mining Province 1 are generally low in sulfur content. Overburden above the Sewell coal (New

River Formation) in Greenbrier County characteristically has little acid producing potential as discussed in Section VII. It is notable that the sandstones and siltstones (cemented with siderite ($FeCO_3$)) and shales of the Kanawha Formation contain numerous small to large (up to 4 feet (1.2 meters) thick) impure sideritic lenses, nodules and stringers. A few irregular marine and fresh-water limestones are almost entirely confined to the Kanawha Formation.

The physiography of Surface Mining Provinces 2 and 3 is a maturely dissected plateau area confined to northern and western West Virginia. Steep slopes rise 500 to 600 feet (150 to 180 meters) from narrow bottom land to narrow sinuous ridges in the area between the Ohio and Monongahela Rivers. The area is easily accessible hill country. Farther east the relief increases and the area becomes more mountainous in Surface Mining Province 2.

The principal coal production of the area is from one seam, the Pittsburgh coal which produces about 25 percent of the State's coal annually. Much of the Pittsburgh coal is produced by underground methods in Harrison, Marion, Monongalia, Marshall and Ohio counties. Smaller tonnages of Pittsburgh and Redstone coals (Figures 6 and 40-46) are produced by surface methods in Braxton, Gilmer, Lewis, Upshur, Barbour, Harrison and Taylor counties. A much smaller amount of coal is produced in northern West Virginia from coals older than the Pittsburgh by surface mining and generally small underground mines (Figures 8-11, 44-49).

The beds (Pottsville, Allegheny, Conemaugh and Monongahela of Pennsylvanian age and the Dunkard of Permian age) were deposited in the younger and more stable of the two basins of coal dèposition in West Virginia (Figure 2). This basin shelved to the southwest as indicated by the disappearance of coals in that direction (Figures 6, 7, 8 and 9), and subsided to the north in the direction of maximum developments of coal and limestone in southwestern Pennsylvania.

For this discussion, the section is divided into two groups each depicting its own unique geologic characteristics. The division between the two groups is transitional and is arbitrarily placed on the Saltsburg Sandstone as discussed above (Figure 2).

The lower group or Surface Mining Province 2 includes beds of the Pottsville, Allegheny and lower Conemaugh. The principal coals are the Lower Kittanning, Upper Freeport and Bakerstown, however numerous other coals, viz, Middle and Upper Kittanning, Lower Freeport, Mahoning and Brush Creek, have been produced generally in small underground mines or in contour surface mines.

Beds of Surface Mining Province 2, containing generally irregular sandstone and shale sequences and thin although locally thick multibenched seams of coal, are present along a narrow strip of the Burning Springs anticline and along the Ohio River in the northern extremities of the northern Panhandle of West Virginia. The principal reserve of coal is present in the Allegheny Mountain Section of the Appalachian Plateau and contiguous areas to the west. Structural activity in the Allegheny Mountain Section resulted in a series of enechelon folds (upwarps and downwarps) in Randolph, Barbour, Tucker, Preston, Mineral and Grant counties, West Virginia. This trend plunges out farther south in West Virginia but continues north across western Maryland into Pennsylvania. It is believed that deformation was active during the deposition of the beds resulting in part in the irregularities in the physical and chemical characteristic of the coals and associated rocks of Surface Mining Province 2. Generally, the coals are best developed over the axes of the synclines (downwarps) and in instances where the beds have not been eroded are less well developed over the axes of the anticlines (upwarps).

The variable chemical characteristics, i.e., volatile matter, fixed carbon, ash and sulfur, within the same seam reflect the complexity of the depositional and structural history of the beds of Surface Mining Province 2. In eastern counties the coal may have a local volatile matter of 14 to 19 percent, a semibituminous coal; farther west the coals will have a volatile matter ranging from 22 to 38 percent with a commensurate decrease in the fixed carbon to between 50 and 60 percent. Analyses of mining sections of the coals show sulfur oscillating between 0.5 and 3.0 percent and ash content varying from 4 percent to over 15 percent depending on the number of erratic partings in the mining section (Appendix B, Table 68). Locally the Lower Kittanning and Upper Freeport coals were formerly mined by underground methods for metallurgical purposes.

The upper group or Surface Mining Province 3 includes beds of upper Conemaugh and Monongahela units of Pennsylvanian age and the Dunkard Group of Permian age. The coals are considered to be high volatile and high sulfur but locally both the Pittsburgh and Redstone (Figure 6) are low sulfur coal and suitable for metallurgical purposes. The principal coal of the area is the Pittsburgh which is mined generally by underground methods throughout the basin. The Pittsburgh and Redstone coals are mined by underground methods and surface methods in Barbour, Upshur, Taylor and Harrison counties and principally by surface methods in Lewis and Gilmer counties. In these counties the volatile matter ranges between 32 and 40 percent; the fixed carbon between 50 and 62 percent; and the ash between 4 and 12 percent depending on the number and thickness of generally thin regular partings in the mining section (Appendix B, Table 67). Minor quantities of Redstone coal are mined in Monongalia and Mason counties. Below the Pittsburgh, the Harlem, Elk Lick and Little Clarksburg coals are mined by surface methods in Preston, Mineral, and Grant counties and above the Pittsburgh, the Sewickley and Waynesburg are mined locally by surface mining in Monongalia County.

The relationship in this shifting facies shows alternating dusky red and yellow mudstone and shale and associated sandstones on the southwest encroaching in a transitional facies with sequences of gray beds composed of mudstone, limestone, coal, shale and sandstone. The latter beds were deposited in the lacustrine-swamp environment or gray facies. To the southwest of the gray facies, the section loses limestone first and then coal (Figures 6 and 7), gray shale and mudstone intertongue with red shale and mudstone, and sandstone becomes a more dominant part of the section. Farther southwest all units become dusky red and yellow shale and mudstone and massive to thin bedded sandstone. The large area, adjacent to the surface mining limits of Surface Mining Province 3 (Figure 1) and barren of prospective minable coal, in central and southwestern West Virginia is underlain by the red facies.

SECTION V

SOIL CONSIDERATIONS

In Surface Mining Province #3 of North central West Virginia, calcareous shales or mudrocks, and limestones in the Pittsburgh, Redstone Sewickley intervals provide an abundance of silt and clay textured materials rich in carbonates, which have contributed to the formations of moderately deep or deep soils with slightly acid or nearly neutral lower subsoils. Such soils are adapted to production of forage crops and are responsive to proper liming and fertilization. However, hillside slips are serious on many slopes, causing irregular topography that is difficult to mow or manage. In addition, overgrazing and land slips often contribute to serious erosion by runoff.

As indicated in the preceding Section, the geologic boundary between Surface Mining Provinces #2 and #3 is drawn at the top of the Saltsburg sandstone. Moreover, from the soils standpoint, as well, the boundary corresponds with soil changes since sandy, highly leached, acid, siliceous soils occur over the Saltsburg sandstone in contrast to the finer textured and more fertile soils mentioned in the main Pittsburgh, Redstone, Sewickley intervals. Even so, it is apparent that undisturbed soils as well as minesoils associated with the Bakerstown and Brush Creek coals between the Saltsburg and Mahoning sandstones are more like the fine textured soils of the Pittsburgh, Redstone, Sewickley than they are like the soils over the Mahoning sandstone and sandstones of the underlying Alleghany Formation. Thus, as stated under "Geological Considerations" (Figure 2) from the pedologic point of view, the boundary between Provinces #2 and #3 could be drawn at the top of the Mahoning sandstone rather than the top of the Saltsburg. This would place the knobs of Bakerstown coal that occur in Preston, Grant and Mineral Counties, within Province #3 rather than with the Freeport and older coals and overburdens of Province #2.

Prominent soils of this part of Province #3 are Westmoreland (upland slopes) and Clarksburg (colluvial slopes). Eastward, on Province #2 sandstones the major soils are Dekalb and Cookport (upland slopes and ridgetops) with Laidig and Buckhannon on colluvium. The upland soils are not only coarser textured than uplands of Province #3, they also lack or have only weak argillic subsoil horizons compared to much greater clay migration into argillic horizons in Province #3. Apparently, exchangeable aluminum cations associated with strongly acid conditions account for limited clay movement in soils on sandstones of Province #2 (Singh, et al, 1970).

CLASSIFICATION, MAPPING, USE AND MANAGEMENT OF MINESOILS---GENERAL

Prior to the development of the new comprehensive soil classification system by the National Cooperative Soil Survey, minespoil was not considered to be soil. It was identified in mapping legends as a miscellaneous land type and was delineated and named as "Strip Mine." Mine spoil was not examined and studied in the detail required to enable one to make meaningful statements in regards to its use and management.

In the new soil classification system, Soil Taxonomy, Soil Conservation Service, U.S.D.A., soil is defined as "the collection of natural bodies on the earth's surface, in places modified or even made by man of earthy materials containing living matter and supporting or capable of supporting plants out-of-doors." In this system, soils are classified on the basis of characteristics which can be observed or measured in the field and in the laboratory. The system is hierarchical and from the highest category to the lowest is comprised of: Orders, Suborders, Great Groups, Subgroups, Families, and Series.

The comprehensive system is broad and flexible enough to permit the definition of categories as necessary to accommodate diverse minesoils and to further their scientific study as well as their effective use and management. We suggested previously (West Virginia University, 1971) that spoils and coal wastes from mining can be studied and classified on the basis of soil profile properties, the same as other soils and can then be incorporated into the comprehensive system of soil classification. This does not mean that categories have already been formally defined that are adequate to include all minesoils.

In our proposal, minesoils would be classified at the Order level as Entisols. Entisols are recent soils that have little or no evidence of development of pedogenic horizons.

Presently, there are five Suborders in the Order of Entisols. These are as follows:

1. Aquents - soils which, if they are not artificially drained, are wet most of the year;

2. Arents - soils which have fragments of diagnostic horizons;

3. Psamments - soils which are sandy;

4. Fluvents - soils which have formed in recent water deposited sediments; and

5. Orthents - soils which occur on recent erosional surfaces.

We are of the opinion that none of these suborders would adequately accommodate minesoils. In our proposal, a new suborder, Spolents, would be established for minesoils. Spolents would be defined to include soils which have the following properties:

1. Coarse fragments in disordered arrangement;

2. Coarse fragments and (or) fines that are mottled as a result of inherent composition differences and (or) active weathering processes; and

3. A thin surface horizon containing a higher percentage of fines than underlying horizons.

In addition, void pockets sometime occur under bridges of coarse fragments as a result of exclusions of fines by original placement.

At the Great Group level, we propose that minesoils would be classified on the basis of soil moisture that would be available to support plant growth. In those places, where the soil, in most years, contains sufficient soil moisture to support plant growth, minesoils would be classified in the Great Group of Udspolents.

At the Subgroup level, we propose that minesoils would be classified on the conformity and rock-origin of the coarse fragments.

At the Family level, we propose that minesoils would be classified on the basis of texture, mineralogy, reaction, and soil temperature. These properties are presently used in the comprehensive system to classify soils at the Family level.

Present evidence indicates that pH at the top of the control section, i.e., at 10 inches would probably be a satisfactory indication for family definition. This has been true in profile studies completed to date, which however, have not included deep profiles in Carbolithic or coaly minesoils. In such cases, however, it is considered that extreme acidity, the major concern in Carbolithic Minesoils, would be unlikely unless the pH at 10 inches was below 4.0. This is expected because of the dependence of rapid pyritic oxidation on high oxygen concentrations and on Thiobacillas micro-organisms that are inactive at pH levels above 5.5. Thus, even if we should define the acid categories of soil families in terms of dominant pH within the control section (10 to 40 inches) we are suggesting that pH at 10 inches is likely to be a generally satisfactory criterium for pH status of the entire control section. Reaction classes suggested for the family level are:

Extremely acid, pH 4.0
Acid, pH 4.0 to 5.5
Neutral, pH 5.5 to 8.0

Minesoils could be classified at the Series level, the lowest category in the system, by defining all other significant soil profile properties, such as details of texture, color, mottling, structure, horizons, and pocket inclusions. Since some of these properties, however, are changing rapidly in young minesoils it is judged satisfactory, at present, to delay classification at the series level until the rate of change of minor properties has become relatively slow, or at least 10 years following establishment of vegetation. Such delay does not appear necessary, however, for useful classification and mapping at the family level.

It might be desirable to map phases of certain soil families in order to satisfy specific practical needs. For example, steep slope and extremely stony phases would apply to some outslopes in steep terrain. However, the outslopes might be indicated more satisfactorily in mapping by an appropriate elongate symbol rather than an enclosed area. Other useful phases might be: (1) extremely acid surface phase; (2) weathered topsoil phase; (3) alkaline geologic topsoil phase; and (4) rough surface phase (where use of farm machinery would not be feasible).

Soil testing to determine lime and fertilizer needs for intensive uses would be necessary in addition to the best of classification and mapping. Also, full descriptions of such features as gullies, ponded water, large surface stones, and inclusions of distinctly different minesoils would be a part of the definitions of minesoil mapping units.

Management and land use implications by families are imperfectly tested at present, but several generalizations seem likely to apply. With extremely acid families, for example, covering with at least six inches of favorable material, probably would be a standard recommendation, whereas with acid families liming would be feasible for forage seedings; and with neutral families no liming would be needed.

From the standpoint of available soil, water and fertility, the sandy skeletal, siliceous families would be generally unfavorable for forage production, but would be favorable for roadways, camping, and certain specialty crops. On the other hand, clayey-skeletal and schlickig, neutral families would be most productive as meadowlands, but would lack stability for roadways or stability on steep slopes.

CLASSIFICATION, MAPPING, USE AND MANAGEMENT OF MINESOILS -- WEST VIRGINIA

We are of the opinion that several families of minesoils can be identified in West Virginia as mappable and manageable units. One such family, for example, is the Valley Point Family. This family is named for Valley Point, Preston County, West Virginia, a community in central Surface Mining Province 2.

In our proposal, the classification of the Valley Point family is as follows:

> Plattic Udspolents; sandy-skeletal, siliceous, acid, mesic. Plattic Udspolents includes those soils originating from surface mining in a climatic region where soil moisture is sufficient in most years for plant growth and which contain thick bedded (plate-like) coarse fragments. "Sandy-skeletal, siliceous, acid, mesic" are family modifiers and are defined as follows:

1. Sandy-skeletal - the soil, below a depth of 10 inches, contains 35 percent or more coarse fragments by volume, and the fine-earth has a sandy texture;

2. Siliceous - the mineralogy of the sand fraction of the fine-earth is 90 percent or more quartz or other insoluble minerals;

3. Acid - soil reaction at a depth of 10 inches is between 4.0 and 5.5; and

4. Mesic - the mean annual soil temperature at a depth of 20 inches is between 8°C and 15°C and the difference between mean summer and mean winter soil temperatures is more than 5°C.

From the standpoint of use and management, Valley Point soils form relatively stable land surfaces that will support livestock or automotive traffic without land slippage. Erodibility is relatively slight because of coarse fragments. Lime and fertilizer are essential for revegetation. Seepage waters are acid or extremely acid in part, becoming less acid with time after final placement. Available water retention for plant growth is low, resulting in some plant mortality from drouth. However, the prime difficulty in revegetation is near-surface acidity and aluminum toxicity resulting from weathering of relatively low percentages of pyrite disseminated throughout the unbuffered, acid sandstone.

SUGGESTED MINESOIL FAMILIES THAT MAY OCCUR AS MAPPABLE UNITS IN WEST VIRGINIA

1. Regolithic Plattic Udspolents; sandy-skeletal, siliceous, acid, mesic. Name: Cuzzart family
2. Plattic Udspolents; sandy-skeletal, siliceous, extremely acid, mesic. Name: not assigned
3. Plattic Udspolents; sandy-skeletal, siliceous, acid, mesic. Name: Birdcreek family (This family may prove to be the same as the Valley Point soils.)
4. Fissile Udspolents; loamy-skeletal, mixed, extremely acid, mesic. Name: Albright family (May be acid and not extremely acid.)
5. Fissile Udspolents; clayey-skeletal, mixed, neutral, mesic. Name: Bridgeport family
6. Fissile Udspolents; loamy-skeletal, mixed, acid, mesic. Name: Brandonville family
7. Carbolithic Udspolents; loamy-skeletal, mixed, extremely acid, mesic. Name: Century family
8. Carbolithic Udspolents; loamy-skeletal, mixed, neutral, mesic. Name: not assigned
9. Carbolithic Udspolents; loamy-skeletal, mixed, acid, mesic. Name: not assigned
10. Typic Udspolents; loamy-skeletal, mixed, extremely acid, mesic. Name: not assigned (May not occur in West Virginia as a mappable unit.)
11. Typic Udspolents; loamy-skeletal, mixed, acid, mesic. Name: Canyon family
12. Typic Udspolents; clayey-skeletal, mixed, neutral, mesic. Name: not assigned

13. Schlickig Udspolents; fine-loamy, mixed, neutral mesic.
Name: Mark Twain family (Mo.) (May occur also in West Virginia where calcareous, non-fissile [Schlickstone] mudrocks are abundant.)

14. Regolithic Fissile Udspolents; loamy-skeletal, mixed, acid, mesic.
Name: not assigned

Note that these tentative names may not all occur in West Virginia in mappable units. It is estimated that 10 soil family names may cover the mappable units that are important in the State.

Generalized mapping at the subgroup level could include only the following:

1. Plattic Udspolents (Sandstone minesoils).

2. Fissile Udspolents (Shaly minesoils).

3. Carbolithic Udspolents (Coaly minesoils).

4. Schlickig Udspolents (Silt and Clay minesoils).

5. Typic Udspolents (Mixed minesoils).

6. Regolithic Plattic Udspolents (Weathered sandstone minesoils).

Some representative minesoil descriptions are included as Appendix D.

SECTION VI

METHODS ADAPTED TO COAL OVERBURDEN MATERIALS AND MINESOILS

Evaluation of the soil-forming-potential of various earth materials requires the application of techniques adapted from analytical chemistry, geology, and agronomy. In some cases we have modified existing methods of rock and soil analysis to enable us to more accurately estimate the properties of future soils; and in other cases we have developed new tools which have proven efficient as aids in characterizing the variety of coal overburden materials we have found developing into new soils. Nevertheless, standard references in soil analysis such as those by Jackson (1958) and Black (1965) will be of value to others engaging in overburden and minesoil characterization.

In order to extend the usefulness of results obtained during the project reported herein, we include, in pages following, step-by-step procedures for certain techniques where they may be unique or deviate substantially from methods familar to the average analyst.

Acquisition of samples of coal overburden materials have been facilitated by keying project field work with times when cooperating surface mine operators are drilling exploration holes either by solid coring or compressed-air drills. A routine procedure for collecting incremental overburden samples as rock chips expelled by air-drilling follows.

PROCEDURE FOR COLLECTING ROCK CHIP SAMPLES FROM BLAST HOLE DRILLING OPERATIONS

Materials

1. Long handle shovel (common round pointed garden shovel is adequate).

2. One-pint plastic-coated cardboard round ice cream containers with covers (Plasti-Kan, or No. 16 Tall Nestyle; Sealright Co., Inc., Fulton, N.Y.). One container for each foot depth of rock drilled, or for each sample obtained.

3. Felt-tip pen (Magic-Marker) or other tool for legibly labelling sample container.

4. Crate (e.g. apple crate) or heavy corrugated paper carton to transport rock-filled containers.

5. Drill rig, rotary bit, compressed air type, to expel drill chips from bore hole (Robbins Rotary Drill Model RR-T or similar type is adequate).

6. Notepad to record miscellaneous data, such as location, total depth drilled, unusual drilling conditions encountered, changes in rock type encountered at various depths, and depth of drill bench with respect to original land surface.

General considerations

1. To obtain the most information, the samples should be taken where overburden depth is the greatest, e.g. top of a hill, or the farthest strip cut into a slope.

2. Where more than one column of rock chip samples is collected on a job, the lateral distance and indication of either upslope or downslope of a previous sample should be noted and recorded.

3. A brief sampling site notation should be established to label sample boxes unmistakenly; e.g. Sew-1, where Sew indicates a Sewickley overburden on the operation being sampled, and -1 indicates the first borehole sample; Sew-2 would indicate a second borehole in the same area or even on the same drilling bench.

4. Sample sites should be geographically located. A suitable method is to locate the spot on a 7 1/2 minute U.S.G.S. Topographical Map, and using a ruler, determine the latitude and longitude coordinates in degrees to five decimal places.

Method of sample collection

1. The drive mechanism suspension chain on the drill rig is examined to determine the number of links per foot. A one-foot depth incre-

ment is approximated by marking, with a dab of grease or other mark visible through the dust, successive link pins that occur about 12 inches apart (on a commonly used Robbins drill rig every sixth pin is 13 1/2 inches). Exact one-foot sample increments are not required, as long as the actual distance of the increment is marked either on a sample box or in the field note book.

2. Sampling is started beginning with the first one-foot increment drilled from the levelled bench that the rig is parked on.

3. The shovel is held under the dust apron almost touching the rotating drill extension and the air-expelled rock chips are allowed to collect on the shovel as the bit lowers one foot.

4. The lowering of the drill bit can be followed by observing as the marked link pins on the suspension chain pass a predetermined point or mark on the frame of the drill rig.

5. The shovelful of material collected from drilling one foot is dumped into the pint box; material overflowing the box is discarded, under the assumption that an average of the material on the shovel has been retained in the sample box.

6. Samples are marked in the order, 1, 2, 3.....etc., collected from the surface downward.

7. Occasional boxes are marked with the locations abbreviations to aid in organization.

8. The filled pint boxes are placed in a crate or heavy carton, along with a page of accompanying field notes, and transported to the laboratory.

9. In mining operations where the mine operator is using a blast hole drill such as the Bucyrus Erie 50-R or 61-R, which is of a different design and construction than the truck-mounted drill used in the work reported here, the method of recovering the rock chip samples needs to be modified. Since these writers have no field experience with the center-platform type of drill, it is suggested that the ingenuity of local drill operators be utilized to secure samples.

In regions where blasting is not practiced to shatter the rock prior to removing the overburden, samples are obtained by hand sampling with a rock hammer in incremental units throughout the depth of material to be evaluated. Where the air-drill rig is parked on a bench below the original land surface, the material removed by a scraper or dozer is hand sampled, at a nearby exposure, from the level of the drill bench up through the original topsoil.

Where exploration test cores, commonly 2-inch diameter, are available for overburden studies, detailed geologic logging is undertaken in addition to sampling for chemical and physical analyses. The detailed procedure for core characterization and sampling follows.

PROCEDURE FOR LOGGING AND SAMPLING EXPLORATION CORES

In the Field

1. All pertinent information about the core is recorded. (a) Location, (b) Total length of core, (c) Coal seams involved, (d) Depth from land surface to top of core, and (e) Elevation of the land surface.

2. Sampling and logging starts from the top of the core.

3. The core is divided into the six rock types, sandstone, shale, mudrock, limestone, intercalate, carbolith, and chert, and the rock type and its thickness are recorded along with color (red, green, etc.), fossils (plant or animal), slickensides (prominent or present), nodules and any other descriptive information which can be readily observed.

4. If a rock member is 5 inches thick or less, it is logged but not sampled unless it is a layer of special interest, such as containing much visible pyrite, limestone, etc.

5. When there is a rock layer of considerable thickness, say 30 feet, the number of samples taken from this section depends on the rock type. Sandstone, Intercolates, and Chert are normally sampled every 5 feet; therefore, there would be 6 samples taken in a 30 foot section of any of the afore mentioned rock types. If the 30 foot section were Carbolith, Mudrock, Shale, or Limestone, we would take 10 samples from this section because these four rock types are being sampled every 3 feet.

6. When an obvious change in properties, such as penetration of the weathered zone below the land surface, occurs at some point within a rock type, the two zones of the rock type are recorded and sampled as different members.

7. Samples, approximately 4 inches long, are taken from the center of the material represented. If the rock is sampled every 3 feet then the sample would come from the center of the 3 foot section.

8. When logging and sampling an exploratory core in the field or at the core storage area has been completed, the log book should contain the following information: (a) sample depth, (b) rock type, (c) thickness of rock type, (d) descriptive material such as color, slickensides, fossils, nodules, etc.

In the Laboratory

1. The samples are logged again in more detail. In the field the sample was put into a class such as Mudrock so in the laboratory it will be further classified as to its being fissile, non-fissile, or nodular.

2. The hardness of the sample is recorded. Only 3 ranges (0-3; 3-5; > 5.5), are used on Moh's scale of hardness, where the fingernail has a hardness of 2.5, a knife blade is 5.5 to 6, and quartz is 7.

3. The color of the sample is recorded using the standard color chips found in the Munsell Soil Color Charts.

4. The streak of the sample on a porcelain plate or white chert rock is checked for "Value" using a Munsell color book. Carboliths have a streak value of 3 or lower, indicating carbon.

5. Finally, the samples are examined for fossils, slickensides, carbonates, nodules, etc., and such finds are recorded.

GRINDING PROCEDURE FOR COAL OVERBURDEN SAMPLES

Reduction of field samples of coal overburden materials to a form convenient for use in various laboratory analyses has been accomplished with simple grinding equipment. More complex commercially available mechanical grinders are also suitable but working procedures have not been investigated. The sample processing steps routinely used by technicians on this project are included here.

Materials

1. Samples of rock in one-pint boxes (or other containers occasionally).
2. Mortar and pestle, cast iron, six inch diameter, two pint capacity. (Cat. No. 12-976, Fisher Scientific Co.; or similar equivalent).
3. Sieve, with receiving pan, 5-inch diameter, 60 mesh (0.25 mm openings).
4. Snap cap plastic vials, about 50 cc capacity (15 dram).
5. One quart (32 oz.) plastic cottage cheese container with cover.

Methods

1. The sample from the field, or that portion which is not needed intact for physical analyses, should be crushed so that all particles are about 1/4" or smaller, if the field sample is not already this fine.
2. The entire pint of field sample is then placed into the one-quart container, the cover applied, and the material rolled and tumbled until thoroughly mixed. A small suitable commercial mixer may also be used if available.
3. Approximately two heaping teaspoons full of the mixed material is then placed into the mortar and pulverized with the pestle.
4. After grinding a short time, the sample is poured from the mortar into the sieve and the sieve is gently shaken.
5. The sample particles larger than the sieve openings are returned to the mortar for further grinding.
6. The entire sample originally placed in the mortar is repeatedly ground and sieved until the entire sample passes through the 60 mesh sieve.
7. The pulverized sample contained in the sieve receiving pan is thoroughly mixed by quartering on a clean paper, or is mixed in an appropriate commercial mixer.
8. The homogeneous pulverized sample is then transferred to a 50 cc plastic vial for laboratory use. The sample identification pre-

sent on the field box is transferred to the plastic vial. The unused portion of the field sample is transferred to the storage room.

PROCEDURE FOR PREPARING MINESOIL SAMPLES FOR SOILTESTING LABORATORY ANALYSES

Minesoils which have been taken for evaluation of available plant nutrient status are prepared for chemical extraction in a manner similar to that used routinely by West Virginia Soil Testing Laboratory. This procedure follows.

Materials

1. Samples of soil in one-pint boxes (or other containers).
2. Wooden rolling pin (kitchen-style).
3. Sieve, with receiving pan, 8-inch daimeter, 10 mesh (2.0 mm openings).
4. Brown heavy Kraft paper.

Methods

1. The sample from the field should be air-dried; pour out onto a square of brown paper and allow to dry.
2. The entire field sample, a portion at a time, is placed between two sheets of brown paper and crushed by moderate rolling over the top sheet with a rolling pin.
3. After crushing a short time, the sample is poured from the lower sheet of paper into the sieve and the sieve is gently shaken.
4. The sample particles larger than the sieve openings are returned to the paper for further crushing.
5. The entire field sample is crushed and shaken on the 2mm sieve.
6. The pulverized sample contained in the sieve receiving pan is thoroughly mixed by quartering on a clean paper, or is mixed in an appropriate commercial mixer.

7. The homogeneous crushed sample is then transferred back to the field sample box. Rocks and other material that does not crush easily to pass the 2 mm sieve is discarded or is saved in another container, appropriately labelled, if the project leader so specifies for a particular study.

8. If the sample is to be analyzed for total sulfur, calcium carbonate equivalent, or chemical species other than available nutrients, a sub-sample of the 2 mm material is pulverized to pass a 60 mesh (0.25 mm) sieve.

SULFUR DETERMINATION

Among the various chemical analyses to which overburden and minesoil samples have been subjected, pyritic sulfur content is most important when considering toxicity or potential toxicity from acidity. Pyritic sulfur content, knowledge of which allows calculation of the maximum amount of acid that might be produced during the weathering of a rock, was estimated from the total sulfur content after the sample has been leached to remove sulfates. The LECO Induction Furnace with Automatic Sulfur Titrator is utilized for the sulfur analyses (Beaton, et al, 1968; West Virginia University, 1971). The step-by-step procedure utilized in the instrument operation follows.

Simplified procedure for determination of total sulphur using the LECO model 521-400 Induction Furnace with Variable Temperature Control Transformer and Timer and model 532-000 Automatic Sulfur Titrator

General Considerations -

a. In the case of coal or very high carbon shale samples, sandwich sample (0.100 gm) between two scoops of MgO which will prevent splashing of sample. A longer time of running may be expected with such samples.

b. Some samples, e.g. coal, when first placed in the furnace may change the color of the solution in the titration vessel to pink or purple (probably due to organic matter being driven off from the sample).

Some samples may contain halogens (I, Cl, F) which darken the solution in the titration vessel and will therefore produce S results that are low. This problem if encountered, may be eliminated by the use of antimony in a trap between the furnace and titration assembly.

c. Generally, with low chroma samples (shale) or other types where high sulfur content might be present, either 0.250 or 0.1000 gram samples should be run first. If sulfur is not detectable or more accurate values are desired in this sample weight, increase sample size to 0.5000 gms. and rerun.

Sample Preparation -

a. Place 1 0.2 ml scoop, level full, of iron chips in crucible, then

b. Weight exactly 0.500 grams of 60 mesh sample into the crucible.
   (1) For samples such as shale and coal, that contain or are suspected to contain over 1% sulfur, use only 0.100 g.

c. Add 1 scoop of MgO, about 0.5 mm^3.

d. Add 2 scoops of Fe powder and one Cu ring.

e. After adding each component, gently shake the crucible to evenly cover the bottom.

f. Place one porous cover on the crucible. (cover may be turned over and reused)

Solution Preparation -

a. Potassium iodate titrant:
   (1) 1.110 g KIO_3/L, multiply buret reading by 5 (1/2 g sample; 0.005 - 1.00 % S Range)
   (2) 0.0444 g KIO_3/L, multiply buret reading by 0.200 (1/2 g sample ; 0.0002 - .040 % S Range)

b. Hydrochloric acid solution: 15 ml conc. HCl/L H_2O

c. Starch solution: Use only arrowroot starch. Add 2 g Arrowroot starch to 50 ml H_2O; stir well. Separately boil 150 ml H_2O and to this slowly add the 2 g starch solution, stirring constantly. Cool and add 6 g potassium iodate to the solution; pour this solution into the polyethylene starch dispenser. Do not use starch over 5 days old.

Instrument Operation -

a. Read entire manuals on both LECO Induction Furnace and Automatic Titrator.

b. Turn ON "Filament Voltage"; grid tap to high position.

c. Turn on titrator — upper left switch (Above "Endpoint Adjust")

d. Set timer switch to ON, adjust timer to 8 minutes, or a time sufficient to satisfy instructions p. and q.

e. Set "Titrate-Endpoint" switch to its middle position.

f. Slosh carboys containing HCl and KIO_3 to mix the condensate on the unfilled walls of the container.

g. Fill iodate buret.

h. Fill titrating chamber to mark; add one measure of Starch; bottom of meniscus shall be 2 3/8" below top of chamber.

i. Turn on oxygen; set pressure to 15 psi, flow rate to 1.0 liter per minute.

j. Turn "high voltage" ON.

k. Place sample crucible on pedestal, making sure it is centered; carefully raise sample fully and close switching lever. Make sure sample platform makes airtight contact when closed; as evidenced by vigorous bubbling in top of titration cell.

l. Turn switch to "Endpoint".

m. After a few seconds when titrant level has stopped falling and titrating chamber is a deep blue color, refill buret or note and record initial buret reading; turn switch to "Titrate". (See x. instruction also)

n. Push RED button on timer to start analysis.

o. While a sample is being titrated, add the final quantities of iron and tin and copper to the next crucible.

p. Plate current must go to 300-350 ma for at least 15 seconds during the analysis; if not, rerun sample.

q. Adjust to prevent Plate Current from exceeding 350 ma.

r. When buret does not change reading for 2 minutes, and Plate Current has achieved 300 to 350 ma, it can be assumed that all of the sulfur has been driven from the sample. If buret is still changing when timer shuts off instrument, set Timer Switch to OFF, which restarts furnace, leave furnace on until buret is stable for 2 minutes, then turn Timer Switch to ON.

s. Set "Titrate-endpoint" to middle position. (IMPORTANT)

t. Lower sample platform, remove crucible using tongs, place fresh sample crucible in place, but do not close sample chamber.

u. Drain titrating chamber and refill every 3rd sample, or more if a large quantity of titrant was used by the previous sample. Slightly drain titrating chamber to maintain original level.

v. Refill KIO_3 buret.

w. Close sample chamber, making sure it is tight.

x. Switch to "titrate", or, if it is known that sample will evolve SO_2 slowly, leave switch at Endpoint - this acts as a "Fine" control allowing buret valve to discriminate smaller increments.

y. Continue from "n" above.

To Shut Down -

a. Turn "Titrate-Endpoint" switch to mid position.

b. Turn off main O_2 valve on top of tank.

c. Turn off "High Voltage".

d. Turn off Automatic titrator (see 3 c.)

e. Drain titration chamber; flush once with a chamber full of HCl solution or water, cover and leave stand.

f. If O_2 has stopped bubbling in H_2SO_4 solution, turn off small knurled valve on gage outlet.

g. Turn off "Filament Voltage".

Maintenance -

Periodically clean titration chamber and associated glassware with acetone or conc. HCl.

Sulfate removal from minesoil and overburden samples prior to Total sulfur determination in LECO Furnace

Materials -

a. 28 mm I.D. polyethylene funnel

b. 5.5 cm glass fiber filter paper

c. Acid-inert filter funnel holder (polyethylene)

d. 2:3 HCl

e. Mariotte bottle, at least 500 ml capacity, with height of outlet capillary adjustable to regulate outflow rate.

Procedure -

a. Taking care to not sharply crease the glass fibers, fold a filter to fit the polyethylene funnel.

b. With filter assemble on a suitable holder (small plastic vial), place onto pan of a balance and weight 0.500 ± .001 g. of 60 mesh sample into the filter.

c. Place sample and filter onto funnel holder in sink or other suitable pan which can receive outflow from funnel.

d. Charge Marriotte bottle with 50 ml. of 2:3 HCl; start siphon and adjust flow rate into funnel such that funnel does not overflow.

e. After sample has been leached with the acid, rinse out feed bottle and fill with 500 ml. of deionized, distilled water; leach sample with water.

f. After leached sample has dried (overnite airdry or 50°C oven), carefully fold glass fiber filter paper around the sample and transfer to a ceramic crucible for total sulfur analysis in the LECO furnace.

g. Determine sulfur using standard LECO procedure, however add one extra scoop of Fe chips or powder.

POTENTIAL ACIDITY WITH PEROXIDE

Direct oxidation of reduced sulfur to acid with hydrogen peroxide and subsequent titration with a standard base has been suggested as the most attractive method of evaluating the acid potential of "acid sulfate soils" (Brinkman and Pons, 1972). Although they also advocate the use of peroxide oxidation to detect "net potential acidity" in acid sulfate soils containing carbonates, oxidative efficiency is greatly reduced at pH's of 5.8 and above (Jackson, 1958). Earlier investigations (West Virginia University, 1971) showed a close relationship between total sulfur content of fresh overburden samples and the amount of acid measured after the samples were treated with hydrogen peroxide. When the samples consisted of minesoils or weathered overburden materials, sulfate-sulfur, organic content, and calcium carbonate content unpredictably influenced the amount of acidity generated by peroxide treatment. The relationship between sulfur content and generated acidity for forty-nine minesoil and weathered overburden samples, where the samples had been treated with acid to remove sulfates and carbonates before both the sulfur determination and the peroxide treatment has been statistically confirmed. Correlation between the acidity produced, and the pyritic + organic sulphur content, was significant at the 0.001 level, with an r^2 value of 0.970. Acidity could be related to percent sulfur by the equation:

$$Y = 4.93 + 52.29\ X$$

where Y is total potential acidity, expressed as milliequivalents of hydrogen per one hundred grams, and X is percent pyritic + organic sulphur.

Procedure

Note: If the sample contains no Carbonates and no Sulfates, and the pH is less than 5.5 in a 1:1 soil-water suspension, then Step 1 can be eliminated.

1. Place 3 grams of sample (< 60 mesh) into a funnel fitted with filter paper (11.0 cm., Whatman No. 41). Leach sample with 300 ml. of 2:3 HCl (HCl:Water) in funnel-full increments, followed by distilled and deionized water (in funnel-full increments) until effluent is free from chloride as detected by 10% silver nitrate. Airdry filter paper and sample overnight, or place in 50°C forced air oven until dry.

2. Carefully scrape dried sample from paper surface and mix.

3. Weigh out accurately 2.00 grams of sample into a 300 ml. tall form beaker. Add 24 mls. of ACS Reagent Grade 30% H_2O_2 and heat beaker on hotplate until solution is approximately 40°C. Remove beaker from hotplate and allow reaction to go to completion, or for 30 minutes which ever comes first. Three blanks for each batch of samples should be handled in the same manner. Caution: Initial reaction may be quite turbulent when samples contain 0.1% sulfur or greater.

4. Add an additional 12 mls. of Reagent Grade H_2O_2 (30%) to beaker and allow to react for 30 minutes, then place beaker on hotplate at approximately 90 to 95°C, solution temperature, for 30 minutes to destroy any unreacted H_2O_2 left in beaker. Do not allow to go to dryness.

5. Wash down the sides of the beaker with distilled H_2O and make the volume of solution to approximately 100 mls.

6. Place beaker on the hotplate or over a Bunsen burner and heat the solution to boiling to drive off any dissolved CO_2, then cool the solution to room temperature.

7. Titrate the solution, with 0.0100 $\underline{N}$ NaOH that is free of CO_2 and protected from the atmosphere, to pH 7.0 using a glass electrode pH meter. Note: The NaOH must be standarized precisely with $KHC_8H_4O_4$ to obtain its exact Normality which will be used in the calculation.

8. Calculations:

   a. (mls of NaOH) x (Normality of NaOH) x (50) = meq (H^+)/100 g.

   b. meq H^+/100 g. x 0.01 = tons H^+/thousand tons of material.

   c. One ton of H^+ requires 50 tons of $CaCO_3$ equivalent to neutralize it.

NEUTRALIZATION POTENTIAL

The natural base content of overburden materials is important in evaluating potential minesoils. Quantitation of neutralizing bases, including carbonates, present in a rock was accomplished by treating the sample with a known excess of hydrochloric acid, heating to insure complete reaction, and determination of the unconsumed acid by titration with standardized base. This is a modification of the procedure used to measure the neutralizing equivalence of agricultural limestone. (Jackson, 1958)

Procedure for Minesoil or Overburden Material

1. Weigh 2.00 ± grams of sample, ground to pass a 60 mesh (0.25 mm) sieve, into a 250 ml Erlenmeyer flask.

2. Carefully pipet 20.00 ml of 0.1 N HCl (the normality of which is known exactly) into the flask.

3. Heat nearly to boiling until reaction (acid + carbonates) is complete, 5 minutes is usually sufficient.

4. Add H_2O to a total volume of 150 ml, boil 1 minute: cool.

5. Titrate using 0.1 N NaOH (concentration exactly known), to pH 7.0 using an electrometric pH meter.

    a. If the pH of the suspension is greater than 7.0 prior to beginning the back titration with NaOH, it can be assumed that there is a $CaCO_3$ equivalent of over 50 tons per thousand tons of material.

    b. If less than 3 ml of the 0.1 N NaOH is required to obtain a pH of 7.0, it is likely that insufficient acid had been added to neutralize all of the base present. Therefore, to obtain the most reliable results, the sample should be rerun using a greater amount of acid initially added to the sample.

    c. If an exact value of this high neutralizing capacity is desired, rerun the sample using a greater amount of acid initially, or using above procedure but substituting 1.0 N HCl and 1.0 N NaOH.

6. Calculate N.P. using equations (a) through (c).

a. Ml. acid consumed by sample = ml. of acid added to sample, minus ml base required to neutralize sample x

$$\frac{\text{ml of acid (only) in a flask}}{\text{ml of base required to neutralize it}}$$

b. parts $CaCO_3$ equivalent/million parts of soil = (ml acid consumed by sample) x N of acid x $\frac{100}{\text{grams of sample used}}$ x

$$\frac{10,000}{1} \times \frac{50 \text{ grams of } CaCO_3}{1 \text{ gram of } H^+}$$

c. for a 2.0 gram sample:

1. Tons $CaCO_3$ equivalent/1000 tons = ml acid consumed by sample x $\frac{25,000}{1,000}$ x N of acid

2. Tons $CaCO_3$ equivalent/thousand tons of soil = ml x 25.0 x N of acid

d. Maximum $CaCO_3$ requirement for neutralization of acid developed from total sulfur = %S x 31.24 (assuming all sulfur occurs as pyrite or marcasite).

The soil test analyses discussed in Section VIII for pH, lime requirement, available phosphorus, potassium, calcium, and magnesium were carried out on overburden rock material pulverized to pass a 60 mesh sieve and in the case of minesoils, crushed material passing a 2 mm sieve. The analytical procedures for available phosphorus and potassium are essentially those instituted by the North Carolina Agricultural Experiment Station (Nelson, et al, 1953) and used by several Eastern states. Available calcium and magnesium were determined in this same extract. The lime requirement test was that proposed by Woodruff. (Woodruff, 1948).

Analyses for available phosphorus by the sodium bicarbonate extraction, as discussed in Section VIII, were carried out using the method of Olsen, et al (1954) as described by Olsen and Dean (1965). Following is the step-by-step procedure for this method.

PROCEDURE FOR DETERMINING AVAILABLE PHOSPHORUS IN MINESOILS. (MODIFIED METHOD OF OLSEN, et al, 1954)

Materials

1. 50 ml. Erlenmeyer flasks with stoppers, or similar containers for phosphorus extraction step.

2. Funnels, 60 mm diameter, with funnel rack to hold several at a time.

3. Whatman #40 or S & S 589-white, filter paper, 110 mm. diameter.

4. 50 ml. beakers to receive filtrate after extraction.

5. Decolorizing charcoal, Darco G-60 (J. T. Baker Chemical Co.) or equivalent.

6. Balance, capable of ± 0.01 gram accuracy.

7. Shaking machine, Burrell Wrist-Action Shaker, or reciprocating shaker adjustable from about 50-200 excursions/minute.

8. 25 ml. volumetric flasks.

9. Colorimeter or spectrophotometer, with filter or adjustment to provide 660 mu incident light.

10. Cuvettes or matched test tubes to fit above colorimeter.

11. Sodium bicarbonate ($NaHCO_3$) solution, 0.5 M, adjusted to pH 8.5 with 1 M NaOH. Mineral oil added to avoid exposure to the air; stored in a polyethylene container and made fresh every 2 months.

12. Ammonium molybdate, $(NH_4)_6 Mo_7O_{24} \cdot 4H_2O$, solution: Dissolve 15 g. in 300 ml. of warm distilled and deionized water. Filter if cloudy and allow to cool. Gradually add 342 ml. of conc. HCl and mix. Dilute to 1 liter.

13. Concentrated $SnCl_2 \cdot 2H_2O$ solution: 10 g. of large crystals dissolved in 25 ml. conc. HCl. Store in a brown glass bottle in a refrigerator. Prepare fresh every 2 months.

    a. Dilute $SnCl_2$: Add 0.5 ml. of the conc. $SnCl_2$ solution to 66 ml. distilled and deionized water. Prepare the dilute solution for each set of determinations.

14. Standard P solution: Weigh 0.4393 g. KH_2PO_4 into a 1 liter volumetric flask. Add 500 mls. distilled and deionized water and dissolve the salt. Dilute to 1 liter, and add 5 drops of toluene to reduce microbial growth.

15. Dilute P solution: Dilute 20 ml. (pipet) of the P solution from (14) to 1 liter with distilled and deionized water. This solution contains two micrograms of P per ml.

Procedure

1. Add 1.00 g of < 60 mesh rock or soil sample, 1.7 cc decolorizing carbon, and 20 ml of $NaHCO_3$ solution to the 50 ml. Erlenmeyer flask. Stopper the flask.

2. Shake for 30 minutes, at 20°C, using a shaking speed of 2 on a Burrell wrist-action shaker, or 120 excursions per minute on a reciprocating shaker.

3. Filter through filter paper specified; shake flask before pouring suspension into filter funnel.

4. Pipet 10 ml of filtrate into a 25 ml. volumetric flask. (If necessary to interrupt work, stop here)

5. a. Slowly add, with a pipet or calibrated dispenser, 5 ml of Ammonium Molybdate solution. Shake gently to mix well (pH of the solution after adding molybdate should be between 3.0 and 4.0. With some alkaline soils it may be necessary to add more acid in order to assure the indicated pH for consistent color development. However, with minesoils studied, 5 ml of molybdate has been sufficient and has avoided excess acidity with extremely acid samples).

   b. Wash down neck of flask with a small amount of H_2O and dilute to about 22 ml.

6. Pipet 1 ml of the dilute $SnCl_2$ solution into the flask, dilute to volume, and mix immediately holding the top of the volumetric flask tightly closed (gases are generated during this mixing); be sure solution is thoroughly mixed before releasing hand pressure on the cap of the flask.

7. Ten minutes but less than 20 minutes after adding the dilute $SnCl_2$ to the flask and mixing, measure the transmittance (%T) of the blue solution, using the colorimeter or spectrophotometer at

660 mμ. Be sure to understand instructions for operating the instrument correctly.

8. Obtain P concentration from standard curve prepared as follows:

   a. Pipette aliquots, containing from 2 to 25 micrograms of P (this gives a range of from 0.08 to 1.0 ug/ml in the 25 ml flask), of the dilute P solution into 25 ml. volumetric flasks and add 5 ml of the $NaHCO_3$ extracting solution to each flask.

   b. Develop the color as in (4) above.

   c. Plot the %T vs. P concentration in the 25 ml. flask on single-cycle, semilog graph paper, or Absorbance (A) vs. P concentration on linear graph paper.

Calculations

If a 1.0 gram sample is extracted with 20.0 ml of extractant; and a 10.0 ml aliquot of the filtered extractant is taken into a 25 ml volumetric flask for color development then:

ppm available P in the soil=
(ppm P in sample, taken from standard curve) X 50

IMMEDIATE LIME REQUIREMENT DETERMINATIONS

Determinations of the lime requirement of minesoils by $Ca(OH)_2$ titration were discussed previously (West Virginia University, 1971a), and further interpretations appear in Section VIII of this report. A further study, involving 32 minesoil samples selected from an Upper Freeport coal mining area, was undertaken to investigate the suitability of the 5-minute-boiling modification of the $Ca(OH)_2$ incubation reported by Abruna and Vicente (1955). Their method was slightly modified for minesoils and is as follows.

Procedure

Place 10 gm. samples of sieved (10 mesh) air-dry soil in beakers. Dilute with 50 cc of distilled water and add varying increments of 0.03 N $Ca(OH)_2$ solution, depending on the expected exchange capacity and base saturation of the soil. Boil on a hot plate for 5 minutes (intermittent stirring of the samples may be necessary to avoid excessive foaming). Cool in a water tray to 25°C. and determine the pH of the suspension using a glass electrode. Buffer curves relating pH values to quantity of lime are then prepared from these data and used to determine the lime required to raise the soil pH to any desired level.

Figure 12 is a comparison of the two methods for determining lime requirement by titration. The results compare favorably and considerable time is saved by the 5-minute-boiling method. It was found that by boiling the solution for five minutes, the time for reaching equilibrium was reduced from 100 hours to 1 hour.

Certain theoretical considerations in addition to a limited study of data accumulated to date suggest that some relationship exists between the lime requirement of soils as determined by the various buffer methods, and the titratable acidity as detected in the Neutralization Potential measurement discussed earlier.

Figure 13 indicates that Soiltest Lime Requirement (modified Woodruff buffer method) and Neutralization Potential are closely correlated. In these predominantly sandstone minesoil samples positive and negative values of the neutralization potential were used. The high correlation shows that it is possible to predict lime requirement from neutralization potential.

SOIL ACIDITY

There are several constituents which contribute to the development of minesoil acidity. These sources (humus, alumino-silicates, hydrous oxides, pyritic materials and soluble salts) may contribute independently or by interaction. The more common methods of measuring acidity are pH, electrometrically by means of glass electrode, exchangeable acidity using unbuffered KCl, and titratable acidity, using unbuffered solution.

Two important factors which affect soil pH measurements are (1) the soil/water ratio and (2) the presence of soluble salts. The "suspension effect" results in a different pH reading when the electrode is placed in the sediment as opposed to the supernatent liquid. The pH of the sediment is usually lower for acid soils. Ideally, pH measurements should be taken in a "thin paste". At West Virginia University's soil testing laboratory a 1:1 soil/water ratio is used, which gives an ideal thin paste or slurry with some soils. With sandy soils and many coarse or medium textured minesoils the 1:1 mixture must be agitated while the pH is being determined in order to assure suspension. A satisfactory alternative is to use less water relative to minesoil.

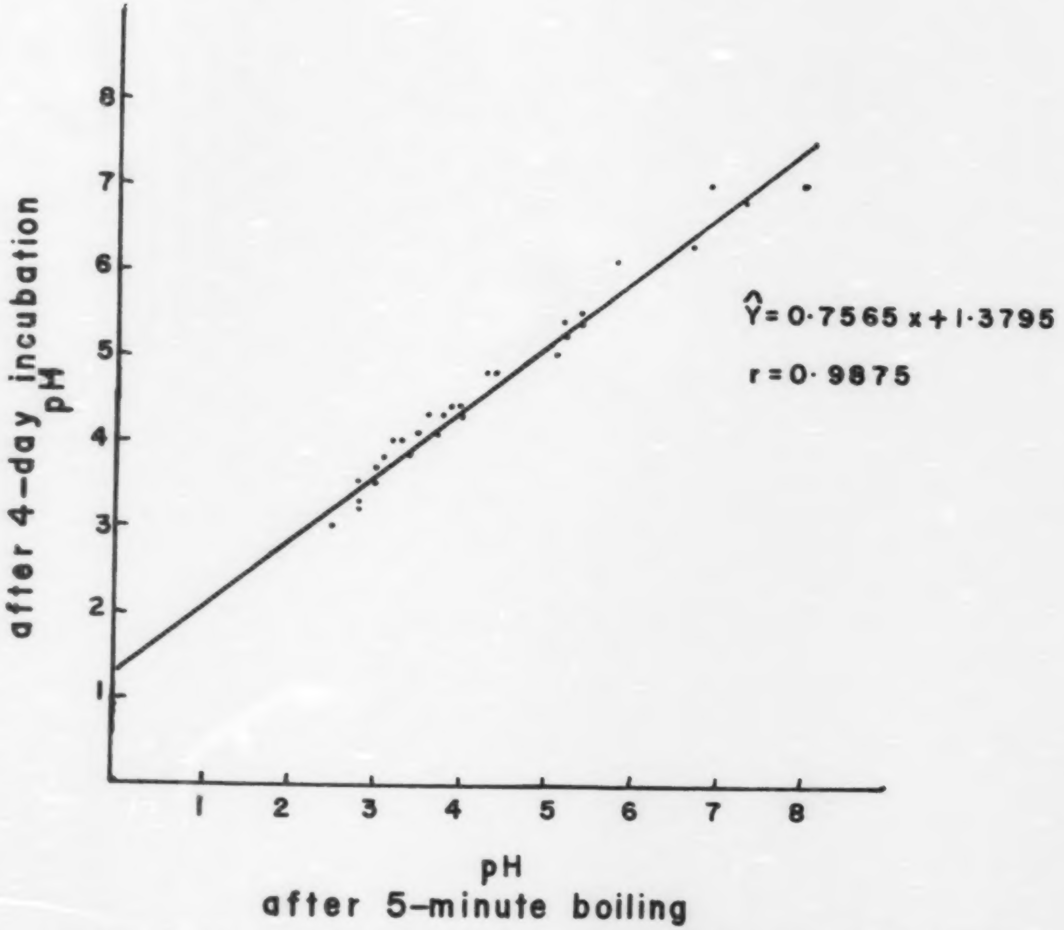


FIGURE 12. COMPARISON OF LIME REQUIREMENTS OF 32 UPPER FREEPORT MINESOIL SAMPLES BY DIRECT $Ca(OH)_2$ TITRATION USING A RAPID 5-MINUTE-BOILING METHOD AND THE STANDARD 4-DAY INCUBATION

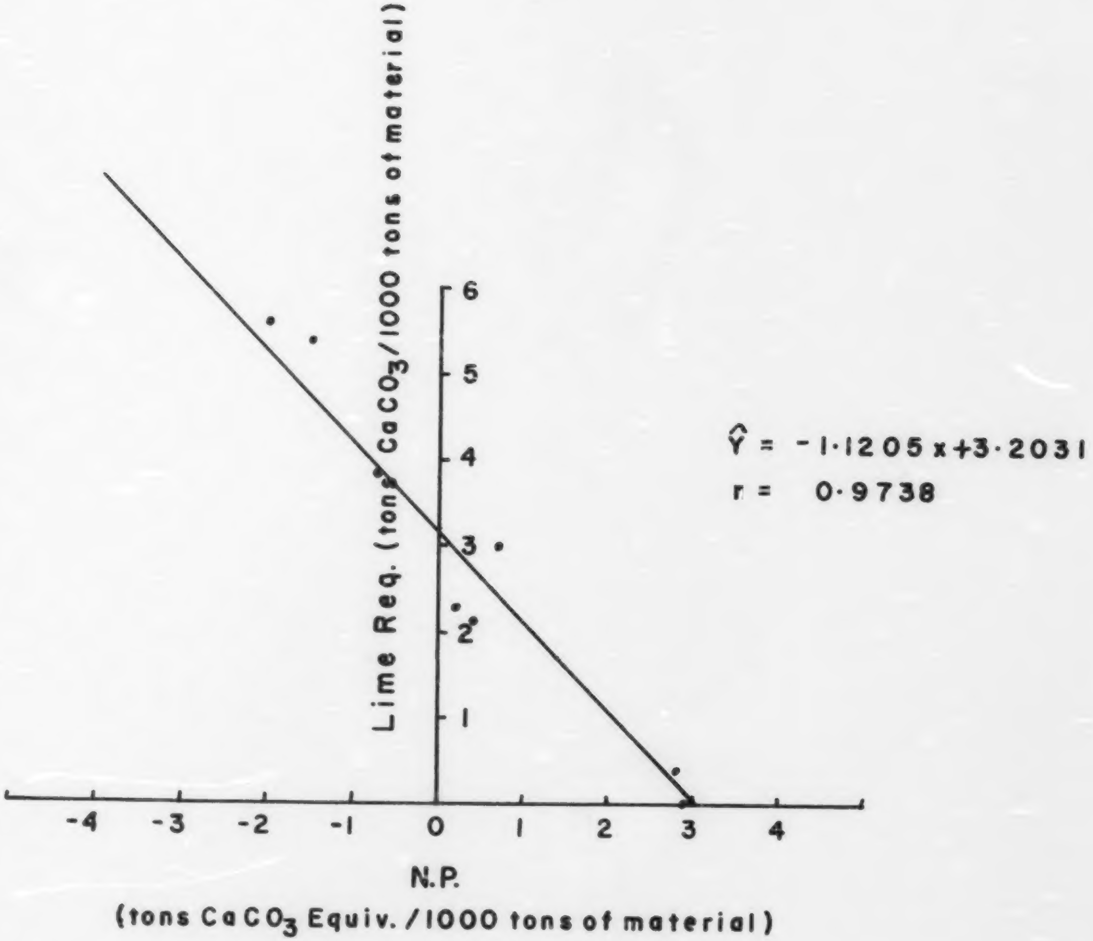


FIGURE 13. RELATIONSHIP BETWEEN SOILTEST LIME REQUIREMENT AND NEUTRALIZATION POTENTIAL.

Soluble salts may have a pronounced effect on soil pH. As the salt concentration is increased the measured pH commonly decreases because the cation of the salt replaces the exchange acidity on the soil colloid releasing the acidity to the soil solution and the pH is decreased.

Two procedures have been used to overcome the salt effect. One method is leaching the soil with water to take out the soluble salts and then measuring the pH. The second method is to add a salt solution instead of distilled water to the soil before measuring pH. One tenth normal KCl and 0.01 M $CaCl_2$ are the salts normally used. The assumption is made that the salts in the soil solution are negligible compared to the salt solution added to the soil. The more common approach in the United States is to determine pH in a distilled water slurry, realizing that significant soluble salts may be present, depending on character of the sample.

The pH measurements of the 1:1, soil/water slurry (agitated to assure soil suspension) were all higher than those of the 1:1, soil/salt solution (Table 1). The relationship between the two methods was good, resulting in a correlation coefficient of 0.858; however, when the pH measurements in water and salt solution were correlated with the extractable aluminum, the correlation coefficients were 0.0319 and 0.0954 respectively. There are two reasons for these poor relationships: (1) All the pH measurements were below 3.7, where acidity is dominantly from mineral acids in the soil solution and the range of pH from 4.0 to 5.5 is where soil acidity is dominated by exchangeable aluminum. (2) There is such a small range of pH values (2.9 to 3.6 for water slurry and 2.4 to 3.1 for the salt solution slurry) that other uncontrolled variables dominate. The exchange acidity of a soil is thought of as that acidity which can be replaced by a neutral, unbuffered salt such as KCl. The titratable acidity is that amount of acidity which is neutralized at a selected pH such as 8.2 for the $BaCl_2$-T.E.A. method. The latter has the rationale of measuring the many different components of soil acidity, and corresponds to the definition of a calcium-saturated soil.

The soil acidity measurements (Table 1) indicate that the $BaCl_2$-T.E.A. method results are higher than those from the 1N KCl method by a factor of approximately 3.0; however, both methods are closely related as evidenced by a correlation coefficient of 0.945. When data of both methods were compared with exchangeable aluminum, the 1N KCl method correlated more closely ($r=0.948$) than the $BaCl_2$-T.E.A. method ($r=0.840$) indicating that the latter measures acidity other than just that which is contributed by the exchangeable aluminum.

Table 1. COMPARISON OF TOTAL ACIDITY AND pH BY TWO DIFFERENT METHODS (JACKSON, 1958) ALONG WITH EXTRACTABLE ALUMINUM ON 3 TO 8 YEAR OLD UPPER FREEPORT MINESOILS.

Sample	Ba Cl_2-TEA pH 8.2 meq H+/100g	1N KCl meq H+/100g	1N KCl meq Al+++/100g	pH	
				H_2O 1:1	1NKCl 1:1
QQ 1-1	12.26	3.87	2.75	2.9	2.4
QQ 1-2	11.28	3.87	3.00	2.1	2.5
QQ 1-3	10.79	3.51	2.56	3.1	2.6
QQ 2-1	8.34	2.50	1.89	3.2	2.6
QQ 2-2	9.48	2.85	1.72	2.9	2.5
QQ 2-3	8.01	2.55	1.99	3.3	2.7
QQ 3-1	13.73	4.89	4.22	3.3	2.6
QQ 3-2	10.46	3.26	2.39	3.2	2.5
QQ 3-3	13.24	5.09	4.81	3.4	2.7
RR 1-1	11.61	3.36	2.70	3.2	2.7
RR 1-2	11.77	3.62	2.92	3.0	2.7
RR 1-3	12.59	4.02	3.17	3.1	2.7
RR 2-1	10.79	3.62	3.11	3.2	2.7
RR 2-2	9.81	3.26	3.00	3.2	2.8
RR 2-3	10.95	3.67	3.00	3.2	2.7
RR 3-1	10.63	3.46	2.50	3.1	2.7
RR 3-2	11.45	3.87	2.92	3.0	2.6
RR 3-3	9.16	3.05	2.22	3.1	2.7
SS 1-1	5.72	1.99	1.61	3.6	3.0
SS 1-2	7.52	2.70	2.22	3.5	2.9
SS 1-3	7.68	2.65	2.22	3.5	2.9
SS 2-1	10.95	3.87	3.36	3.3	2.8
SS 2-2	7.57	2.85	2.22	3.5	2.9
SS 2-3	11.77	3.77	3.31	3.4	2.8
SS 3-1	7.19	2.65	2.22	3.5	2.9
SS 3-2	6.38	2.34	1.83	3.5	2.9
SS 3-3	6.70	2.04	1.67	3.6	3.1

CATION EXCHANGE CAPACITY OF MINESOILS

Soils all have negative charges which are derived from both the inorganic and organic phases. The former contributes negative charges to the soil by isomorphous substitution and ionization of hydroxyl groups of the silica tetrahedron while the carboxyl, phenolic and amino groups found in soil organic matter are responsible for the negative charge arising from the latter. The sum total of these negative charges per given weight of a particular soil is called the Cation Exchange Capacity (C.E.C.) of that soil. On each of these negatively charged sites an exchangeable cation is absorbed and is subject to interchange with cations in the soil solution. This reaction continues until equilibrium is reached between the soil solution and the exchange sites on the soil solid phase; however, the cation exchange process is dynamic and the equilibrium condition is always changing.

The different methods of determining C.E.C. can be placed into three categories: (1) Electrodialyzing or leaching the soil with a dilute acid (HCl) followed by titrating the soil with $Ba(OH)_2$ to pH 7.0 or NaOH to pH 8.5. (2) Summation of exchangeable or extractable hydrogen and the replaceable bases (calcium, magnesium, potassium and sodium). (3) Saturation of the soil with a neutral unbuffered salt (e.g. $CaCl_2$, KCl) or the acetate of ammonium, barium, calcium, or sodium which is buffered at a certain pH (e.g. 7.0 or 8.2) and the amounts of the cations absorbed by the soil is determined. The question of which pH (7.0 or 8.2) is best for buffering salt solutions is unanswered. The former has the rationale of neutrality and is the pH to which soils are generally limed while the latter corresponds to the definition of a calcium-saturated soil. It also appears to correspond with complete neutralization of sorbed ferric iron and aluminum ions.

The C.E.C. of three to eight year old Upper Freeport minesoils was determined by five methods and the results statistically correlated Table 2). Method I and II are saturation techniques while methods III, IV and V are summation techniques. The data of Table 2 indicate several relationships although there is variability between the actual C.E.C. determined by the different methods (Table 3).

Method III (soiltest procedure) was poorly correlated with methods I and II but showed a much closer relationship with methods IV and V. This could be partly because method III is a summation technique like methods IV and V and partly due to the acid extracting solution used in this method. Method III tends to extract more calcium and magnesium which may be in the sulfate form rather than on the exchange complex. The replaceable hydrogen is measured by equilibrating a

Table 2. COEFFICIENTS OF CORRELATION RELATING DIFFERENT METHODS USED TO DETERMINE THE CATION EXCHANGE CAPACITY OF 3 TO 8 YEAR OLD UPPER FREEPORT MINESOILS.

Methods Correlated	I.	II.	III.	IV.
Method I. (Jackson, 1958) NH_4+ Saturation (1 N $NH_4(OAc)$, pH 7.0)	-----	-----	-----	-----
Method II. (Rich, 1961) Ca^{++} Saturation (1 N $CaCl_2$)	.8904	-----	-----	-----
Method III. (Nelson et.al., 1953) Exchange Acidity ($Ca(OAc)_2$, pH 7.0) + Extractable Bases (.05 N HCl - .025 N H_2SO_4	.6452	.6093	-----	-----
Method IV. (Jackson, 1958) Exchange Acidity ($BaCl_2$-TEA, pH 8.2) + Exchangeable Bases (1 N $NH_4(OAc)$, pH 7.0	.8456	.8384	.8289	-----
Method V. (Jackson, 1958) Exchange Acidity (1 N KCl) + Exchangeable Bases (1 N $NH_4(OAc)$, pH 7.0	.8776	.8996	.8039	.9500

Table 3. CATION EXCHANGE CAPACITY OF 3 TO 8 YEAR OLD UPPER FREEPORT MINESOILS DETERMINED BY 5 DIFFERENT METHODS.

Samples	Method I	Method II	Method III	Method IV	Method V
QQ 1-1	6.44	5.61	5.04	12.44	4.05
QQ 1-2	6.54	5.61	4.21	11.32	3.99
QQ 1-3	6.54	4.99	3.53	11.01	3.73
QQ 2-1	4.92	3.62	3.40	8.50	2.66
QQ 2-2	5.06	4.24	3.31	9.58	2.95
QQ 2-3	5.73	3.62	2.58	8.16	2.70
QQ 3-1	12.73	8.48	4.86	13.92	5.08
QQ 3-2	6.78	5.61	4.08	10.68	3.48
QQ 3-3	10.20	9.23	5.60	13.47	5.32
RR 1-1	7.87	5.74	4.92	11.97	3.72
RR 1-2	8.44	4.74	5.03	11.91	3.76
RR 1-3	7.87	7.11	5.00	12.80	4.22
RR 2-1	7.16	5.74	5.80	11.00	3.83
RR 2-2	6.54	5.36	4.20	10.00	3.45
RR 2-3	7.49	5.36	5.75	11.12	3.84
RR 3-1	4.92	3.62	5.33	10.89	3.72
RR 3-2	6.06	4.37	6.12	11.67	4.09
RR 3-3	4.83	3.62	4.53	9.36	3.25
SS 1-1	2.83	3.24	2.61	5.81	2.08
SS 1-2	4.83	3.74	3.42	7.66	2.84
SS 1-3	3.87	3.74	2.60	7.78	2.75
SS 2-1	6.54	5.99	4.28	11.09	4.01
SS 2-2	6.06	4.24	4.16	7.66	2.99
SS 2-3	6.06	5.99	5.13	11.97	3.90
SS 3-1	4.25	3.62	2.57	7.32	2.78
SS 3-2	3.68	3.24	1.72	6.54	2.50
SS 3-3	3.30	3.24	2.51	6.79	2.13

soil sample with $Ca(OAc)_2$ at pH 7.0 instead of pH 8.2 like Method IV. Since the replaceable hydrogen is so important in acid soils the measurement of this cation could be the major difference between these two methods.

Method IV is recognized by many soil scientists as the most reliable procedure to use for determining the C.E.C. of acid soils and only method V is significantly more closely related to it than is method III. Method I, II, and III are similarly related to method IV. Considering the data in Table 1 and Table 2, it may be concluded that methods IV and V are both reliable in estimating the C.E.C. of acid minesoils, with exchangeable hydrogen by the buffered solution (pH 8.2) rather than by neutral KCl solution being the difference in actual values obtained. Method III can be used to estimate the C.E.C. just as well as methods I and II.

ORGANIC CARBON ANALYSIS

The standard procedure for determining carbon in soil is the dry-combustion method which employs a high temperature furnace to convert the carbon to carbon dioxide which is collected and measured. The procedure is slow, limiting the number of samples which can be quickly processed. Another method of determining readily oxidizable organic matter in soil is the wet oxidation method developed by Walkley and Black. This method shows excellent correlation with the dry-combustion method. It is a rapid titration method which determines the readily oxidizable organic matter of soils by chromic acid oxidation with spontaneous heating due to the chemical reaction of 1 N $K_2Cr_2O_7$ and concentrated H_2SO_4.

The method is rapid and gives moderately satisfactory discrimination of humus from the highly condensed forms of organic carbon. Another advantage of this method results from the fact that evolved CO_2 is not measured and a soil sample can contain up to 50% $CaCO_3$ by weight without any interference from the inorganic carbon source. The oxidizable matter in a soil sample is oxidized by the chromate ions and the excess chromate ions are measured by titration with $FeSO_4$ solution. This procedure gives a 60 to 86% recovery of organic carbon and must be multiplied by a factor to get per cent organic matter.

The disadvantages of this type of method are incomplete recovery of organic carbon and the presence of other readily oxidizable material in the soil. Chlorine, higher oxides of manganese and reduced iron will interfere if they are present in any appreciable amounts.

Ignition at low temperatures has also been used for determining organic matter in soils. A weighted oven-dry sample is heated to 350° to 400°C for 7 to 8 hours to oxidize the organic matter. The mineral matter is assumed to be unchanged at these temperatures and the per cent organic matter is calculated from the weight loss. The procedure is simple and large numbers of samples can be processed, but the discrimination between organic matter and mineral matter is not complete. If carbonates are present the sample should be leached with HCl.

To evaluate the Ignition method, it was compared with the Walkley-Black method using Upper Freeport minesoils which were devoid of vegetation and ranged in age from 3 to 8 years. The only organic matter present was contributed by the weathering of Carbolithic rocks.

The data in Table 4 indicate that the results obtained by the Ignition method are almost twice as high as those obtained by the Walkley-Black procedure; however, the degree of correlation between the two methods indicates a very close relationship. This relationship suggests that the Ignition method can be utilized with regression equation to obtain a reliable estimate of easily oxidizable organic matter in minesoils.

PROCEDURE FOR MEASURING PHYSICAL WEATHERING POTENTIAL OF ROCKS

This procedure was developed by combining features of the methods put forth by Bouyoucos (1951), Tyner (1940), Day (1956), and Kilmer and Alexander (1949). The basic principle of this method is to artifically weather rocks by shaking the sample, treated with a mild dispersing agent (Calgon), on a reciprocating shaker for sixteen hours, followed by mechanical analysis of the resulting suspension.

Apparatus

French square bottles, 32 oz., with caps; 10 mesh sieve, 5 inches in diameter; reciprocating shaker; a standard hydrometer (ASTM 152H, with Bouyoucos scale in grams per liter); glass sedimentation cylinders with markings at the 1130 ml. and 1205 ml. levels; analytical balance; drying oven; aluminum foil bread pans; thermometer (°F); plunger.

Reagents

5% Calgon solution; distilled water. The dispersing agent "Calgon" contains sodium metaphosphate with sufficient sodium carbonate to give a pH of approximately 8.3 in a 10% solution.

Table 4. COMPARISON OF ORGANIC MATTER DETERMINED BY IGNITION (JACKSON, 1958) WITH EASILY OXIDIZABLE ORGANIC MATTER DETERMINED BY THE WALKLEY-BLACK (JACKSON, 1958) WET OXIDATION METHOD USING SAMPLES FROM 3 TO 8 YEAR OLD MINESOILS, ALONG WTIH THE COEFFICIENT OF CORRELATION AND THE REGRESSION EQUATION.

Samples	Ignition %	Walkley-Black %
QQ 1-1	6.76	3.68
QQ 1-2	7.96	4.19
QQ 1-3	4.16	2.26
QQ 2-1	7.09	4.28
QQ 2-2	7.32	4.37
QQ 2-3	6.95	4.12
QQ 3-1	30.85	11.79
QQ 3-2	19.68	9.04
QQ 3-3	21.93	10.04
RR 1-1	4.49	2.50
RR 1-2	4.50	2.19
RR 1-3	4.30	2.15
RR 2-1	3.59	1.89
RR 2-2	3.79	2.07
RR 2-3	4.55	2.25
RR 3-1	5.55	2.23
RR 3-2	7.60	2.11
RR 3-3	5.20	2.44
SS 1-1	0.83	0.36
SS 1-2	0.79	0.19
SS 1-3	2.04	0.35
SS 2-1	9.44	3.61
SS 2-2	1.99	0.81
SS 2-3	5.36	2.05
SS 3-1	1.48	0.67
SS 3-2	1.50	0.56
SS 3-3	0.60	0.43

$Y(\text{Walkley-Black}) = 0.3079 + 0.4122\ X\ (\text{Ignition})$

$r = 0.9770$

Explanatory Notes

1. Temperature is quite important to the sedimentation procedure, and although there is a correction factor for temperatures higher or lower than the temperature at which the hydrometer has been calibrated, it is best to carry out the procedure in a constant temperature room or maintain the sedimentation cylinders in a constant temperature bath.

2. Plunger: This can be made out of 1/8 inch diameter wire. At one end of the wire make a circle 2 1/8 inches in diameter; the wire should be manipulated so the handle part extends from the center of the circle for 22 inches. Small rubber bands are spaced around the rim of the circle of wire until the circumference of the circle has been covered and all rubber bands overlap at the center of the circle.

Procedure

1. Intact rock fragments(generally >13 mm) are dried overnight at 50° C.

2. A 100 gram oven-dry sample is taken for all rock types except the non-fissile mudrock for which only a 50 gram sample is used.

3. Put the 100 ± 0.1 g. sample (oven-dry) in a 32 oz. shaker bottle and add 250 ml. of 5% Calgon solution. For a 50 g. sample use 125 ml. of 5% Calgon solution.

4. Fill the bottle with distilled water to within 3 3/4 inches of the top.

5. Cap the bottle snugly and put it on a reciprocating shaker for 16 hours at 120 strokes per minute. Note: the bottle must be lying in a horizontal position on the shaker.

6. The shaker bottle is removed from the shaker and placed in a cold water-ice bath to bring the temperature of the suspension promptly to room temperature.

7. Put a wide mouth funnel in the sedimentation cylinder and insert a 10 mesh sieve in the funnel. Transfer the sample to sedimentation cylinder by pouring the suspension through the 10 mesh sieve.

8. Wash all sediment out of the shaker bottle by holding the bottle at a 45° angle with the mouth of the bottle over the center of the sieve and directing a jet of distilled water upward into the bottle, sweeping all the particles out by the force of the stream of water.

9. Wash the particles caught on the 10 mesh sieve carefully and thoroughly with a gentle jet of distilled water. Do not touch the particles with anything but a stream of water during this washing process.

10. Remove the sieve from the funnel carefully and transfer the material retained to an aluminum breadpan which was previously weighed and recorded. This transfer will be quite easy or difficult depending on the type of rock. To make the transfer without losing material is important. The means of making the transfer can be with a jet of water, tapping it gently off the sieve, picking it off by hand, etc.

11. The aluminum breadpan is put into a drying oven at 105°C overnight and weighed (± 0.1 g.) the next day, then recorded.

12. Fill the cylinder to the upper mark (1205 ml.) with the hydrometer in the cylinder if a 100 gram sample is used; lower mark (1130 ml.) for a 50 gram sample. Use only distilled water.

13. Remove the hydrometer, take the plunger in the right hand holding the cylinder with the left hand and move the plunger up and down in the cylinder strongly while being careful not to spill the contents of the cylinder.

14. After all the sediment is off the bottom of the cylinder, carefully remove the plunger and set the cylinder in a place where it won't be disturbed either by hand or room vibrations and record the time.

15. Hydrometer readings are taken at the end of 40 seconds and at the end of 2 hours. At the appropriate period, gently insert the hydrometer in the cylinder, steady it with the hand and record the reading at the top of the meniscus. Remove the hydrometer gently and wash it. The hydrometer must not be left continuously in the suspension column too long (more than 20 seconds) because particles settle out on its shoulders.

16. Record the temperature of the suspension at the time each reading is taken. For every degree above the temperature at which the hydrometer was calibrated, add 0.2 to the hydrometer reading; for every degree below the temperature at which the hydrometer was calibrated, subtract 0.2 from the hydrometer reading.

17. Correct hydrometer reading for the Calgon in the suspension: for every batch of 5% Calgon solution made, 3 blanks for the 1206 ml

volume and 3 blanks for the 1130 ml volume should be run to get the correction factor for the Calgon in each suspension.

Calculations

$$\% \text{ coarse fragments} = \frac{\text{(Wt. of pan + sample - (Wt. of pan)}}{\text{Wt. of sample}} \times 100$$

$$\% \text{ clay} = \frac{\text{(Temp. corrected 2 hr. Reading minus Calgon correction}}{\text{Wt. of sample}} \times 100$$

$$\% \text{ silt} = \frac{\text{Corrected 40 sec. Reading minus Corrected 2 hr. Reading}}{\text{Wt. of sample}} \times 100$$

% sand = 100 minus [% coarse fragments + % clay + % silt]

ACID POTENTIAL OF COAL

Acid production from abandoned underground coal mines results from the same oxidation reactions as found in weathering of pyritic overburden materials, the following technique for estimating acid producing potential of coals has been applied to numerous different coal samples. The study is incomplete, however, significant variation has been found among the many coals tested. The following acid producing potential technique has been designed to simulate natural conditions of weathering and acid production in the absence of microorganisms. An air-water-coal system is used. The purpose of the technique is to produce an actual rather than calculated acid producing potential for comparison of coals.

The technique, at this stage, eliminates or minimizes as many variables as possible. Temperature of reaction is controlled. Biological influences are hopefully eliminated. The properties, volumes, and flushing rate of leaching fluids are controlled. Surface area of reaction is controlled. Influences of units enclosing the coal are eliminated. Samples are continually saturated, thus eliminating cyclic hydration and dehydration effects. In short, the heterogeneity of the system is controlled except for the properties of the coal. The resulting acid producing potential reflects the actual interaction of coal properties to produce acid "without external influence".

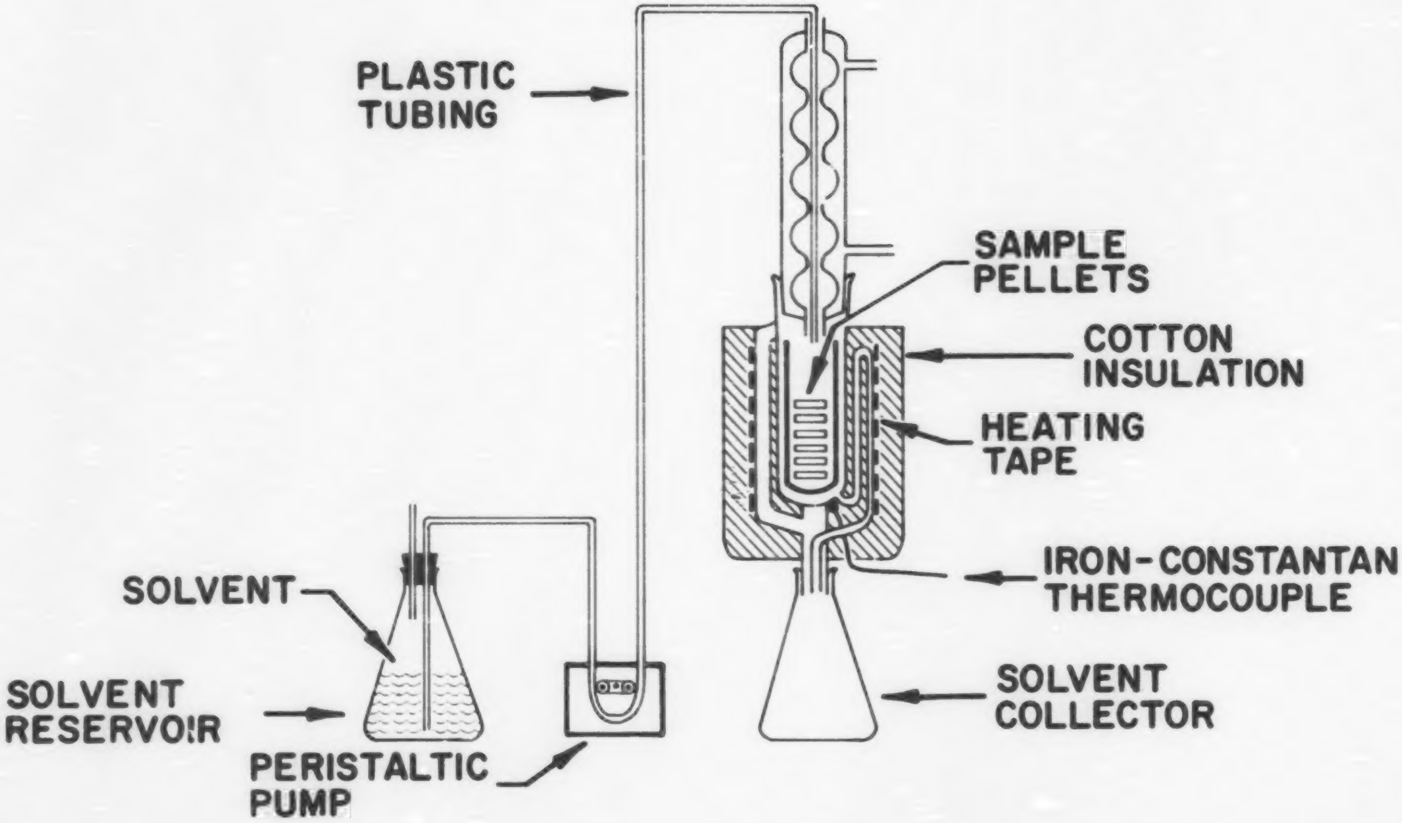


FIGURE 14. SOXHLET EXTRACTOR MODIFIED FOR PROCEDURE TO MEASURE THE RELATIVE ACID-PRODUCING POTENTIAL OF COAL.

Preparation of samples

1. Crush coal sample to less than 10 mesh size in a roll mill or suitable substitute.

2. Grind representative splits to 325 mesh in size in a Spex Mixer-Mill (or suitable substitute). A 65 ml tool steel grinding vial equipped with a cap compression "O" ring is used. The grinding vial is filled approximately 1/3 full with coal; 300 1/8 inch stainless steel balls are added plus 35 ml of methanol; the vial is sealed and the sample ground for 15 minutes. The resultant slurry is poured into an evaporating dish through a wire screen to catch the balls. The vial is washed with methanol as are the grinding balls and screen, catching the wash liquid in the evaporating dish. After the slurry had dried, the cake is repulverized with a rubber stopper.

3. Press 14 cylindrical pellets 32 mm in diameter by approximately 3 mm thick at 20 tons total load for two minutes.

Preparation of the Soxhlet extractors

1. Clean and flush the extractor assembley with distilled water.

2. Thoroughly soak, clean ceramic thimbles with distilled water and drain.

3. Place the thimbles in the extractor assembly, add 85 ml of distilled water to each thimble (this is the maximum standard volume of water that can be added without initiating the overflow siphons.)

4. Turn on the cooling water to the condensors. Turn on the power to the heating tapes and allow the reactors to establish thermal equilibrium at 75°C.

Extraction of Samples

1. Add 300 ml of triple distilled water to the solvent reservoir. Load 7 pellets for which total surface area has been calculated onto brass wire racks (inert plastics are preferable) and lower into the thimbles. A duplicate extractor can be run with the remaining 7 pellets.

2. Turn on the peristaltic pumps. This must be preadjusted to deliver 300 ml of solvent in 100 minutes.

3. Extract for 100 minute - 300 ml cycle.

4. Turn off the pumps, remove the solvent collection flask, and pour the solution (to overflowing) into a 250 ml polyethylene bottle and seal the bottle. Discard excess. Return the solvent collection flask to the extractor and refill the solvent reservoirs to 300 ml. This extraction cycle is run a total of five times.

Data Collection

1. Cool the solutions to room temperature, uncap, and immediately determine the pH of the solution.

2. If the initial pH of the solution is less than 7, determine ACIDITY by titration with standardized 0.02N NaOH to an end point of pH = 7.00.

   If the pH is greater than 7, determine the ALKALINITY by titration with standardized 0.02N HCl to an endpoint of pH = 4.50.

3. Acidity or alkalinity is calculated according to the formula:

$$\begin{matrix}\text{Acid.}\\ \text{or}\\ \text{Alka.}\end{matrix} = \frac{(\text{ml titrant (N titrant) (5000)}}{\text{ml solution}}$$

   with results reported as ppm $CaCO_3$ equivalent.

4. Data is corrected for total surface area and reported in ppm/10,000 mm^2 surface area where the 10,000 mm^2 unit surface area was arbitrarily chosen.

Data Analysis

1. Data can be plotted versus time for a visual comparison between coals of acid production and rates.

2. Data can be analyzed by asymtotic regression to compute end point total acidity and the time necessary to reach this point.

SECTION VII

ACID PRODUCING POTENTIAL AND NEUTRALIZING POTENTIAL

The formation of acid from the oxidation of reduced sulfur compounds in exposed coal and coal overburden materials has been elaborated upon by many other investigators. One objective of this project has been to determine the quantity of pyrite and other potentially acid-forming compounds in various coal overburden and minesoil materials. This has been accomplished by chemical analysis for total or pyrite sulfur.

From the stoichiometry of the reaction of the oxidation of FeS_2 it can be calculated that for a material containing 0.1% sulfur, all as pyrite, complete oxidation will yield a quantity of sulfuric acid that will require 6,250 pounds of calcium carbonate to neutralize one thousand tons of material. Where sulfur in overburden rock is present exclusively as pyrite, the total sulfur content accurately quantifies the acid-producing potential. Removal of sulfates, by methods previously presented, naturally present in some overburdens or resulting from weathering of pyritic materials in a spoil area, allows increased accuracy in predicting the acid-producing potential of materials containing mixed sulphur species.

Sulfur fractionation analyses show that the majority of fresh overburden materials found in areas of study reported by this project contain insignificant amounts of sulfur other than pyritic. This situation may be different in other areas.

Fine-grained euhedral pyrite petrographically observed to be widely disseminated throughout the various unweathered sandstones has been found in sufficient quantity to require up to ten tons or more of calcium carbonate per thousand tons of material to neutralize resultant acidity. Unweathered shales frequently contain similar quantities or more of pyrite, but they also frequently contain neutralizing bases. Total sulfur profiles in several different overburdens, extending from the land surface to the coal to be mined, have been presented (West

Virginia University, 1971a; Grube, et. al., 1972). All overburdens contain an intensely weathered zone below the original land surface, which contains essentially no pyrite. This zone commonly is 20 feet deep or deeper, depending on lithology, degree of structural fracturing of the rock, and position of the water table. Brown and yellow rock colors (high chromas) provide useful clues to pyrite-free materials regardless of whether their position in the stratigraphic section is known.

The natural base (alkali and alkaline earth cations, commonly present as carbonates or exchangeable cations on clays) content of overburden materials is important in evaluating potential minesoils. The quantity of natural, readily soluble bases in a fresh spoil material may be sufficient to neutralize acid at a rate equal to or exceeding the rate of acid production if pyrite is also present in the material. Quantitation of neutralizing bases, including carbonates, present in a rock was accomplished by treating the sample with a known excess of hydrochloric acid, heating to insure complete reaction and determination of the unconsumed acid by titration with a standardized base (this procedure is discussed in Section VI). A balance of the acid-producing potential and neutralizing bases present in the sample was then drawn which indicates the ultimate acidity or alkalinity that might be expected in the material.

An acid-base account, as shown in Figure 15, illustrates the ultimate acidity or basicity of different rock zones in the overburden. This figure was obtained by plotting the values calculated from analytical data as shown in Table 8, which presents a typical summary of data from one field study site. The columns of data presented in the table are explained as follows:

> Depth indicates sequence of samples, from the original land surface or from the coal seam indicated. Intensity of Fiz (or effervescence) indicates whether an observable reaction occurs when 10% hydrochloric acid is applied dropwise to the pulverized sample. A visible reaction (as shown by "1") usually indicates the presence of at least the equivalent of 20 tons of calcium carbonate per thousand tons of material. Color is evaluated on the pulverized sample using Munsel Soil Color Charts. %S is determined using the LECO instrument. The Tons of Calcium Carbonate Equivalent per Thousand Tons of Material is equivalent to tons of lime per acre as normally used in agricultural lime and fertilizer recommendations. The "Maximum Requirement" was calculated from chemical equivalency. The "Amount Present" was determined by the procedure for Neutralization Potential. An "Amount Needed for Neutrality" exists when the value calculated for "Maximum Requirement" is numerically higher

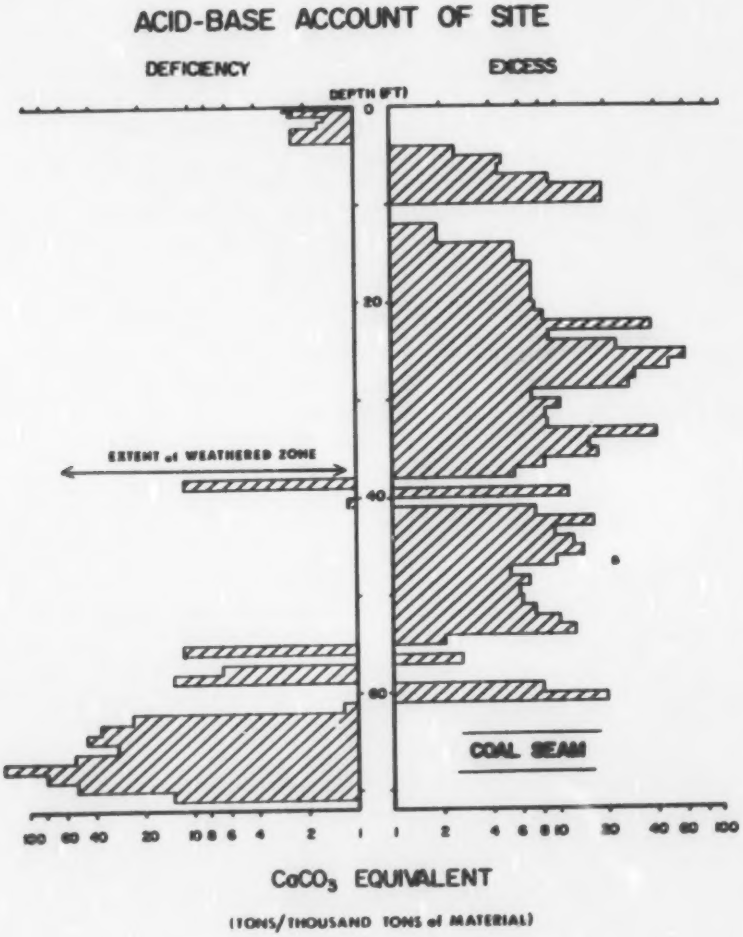


FIGURE 15. ACID-BASE ACCOUNT ILLUSTRATING NET ACIDITY OR ALKALINITY OF A SECTION OF REDSTONE COAL OVERBURDEN

than the "Amount Present". The "Amount Needed for Neutrality" is calculated by subtracting the "Amount Present" from the "Maximum Requirement". In the case of some soils, minewaste material, or certain overburden materials a measurement of "Amount Present" will yield a negative number; when this is subtracted from "Maximum Requirement", "Amount Needed for Neutrality" is the algebraic sum of the two values, "Maximum Requirement" and "Amount Present". When "Amount Present" exceeds "Maximum Requirement", an "Excess $CaCO_3$ Equivalent" will be found. The "Excess $CaCO_3$ Equivalent" was calculated by subtracting "Maximum Requirement" from "Amount Present". The effective excess of bases will be greater than that calculated because "Maximum Requirement" is an upper limit of lime that will ever be needed; under practical conditions this maximum only will be needed in a very long time. In a graphical plot of Acid-Base Account, the values for "Amount Needed for Neutrality" are plotted under "DEFICIENCY", and the values for "Excess $CaCO_3$ Equivalent" are plotted under "EXCESS"; values of less than one ton do not appear on the graph.

Sites represented in the following discussion are identified in Appendices C and E, and where appropriate, they are keyed to the Geologic Cross Sections of Section IV. For example: A-A', 17c means that samples are from Site 17 in Geologic Cross Section A-A'; the "c" indicates that samples are from the third replicate column sampled at Site 17.

SURFACE MINING PROVINCE 3

Details of the composition of much of the Pittsburgh and Redstone overburden material from Surface Mining Province 3 and illustrated in Figure 16 are shown in Tables 5 through 12. Tables 5 to 7 show overburden characteristics from analyses of three borings at the far eastern outcrop of the Pittsburgh coal in North central Barbour County. The Redstone coal position is evident as a thin carbonaceous shale at sample no. 13 in boring 17a. The persistence of the Redstone Limestone is evident in samples 5 to 12 in boring 17a and 4-15 in boring 17c. Boring 17b again illustrates the low sulfur in the weathered zone in rock near the land surface, in this case the Cedarville Sandstone. The lower samples of boring 17b show increasing potential toxcity in the carbonaceous shales overlying and associated with the Redstone coal position. The small amounts of "Excess $CaCO_3$ Equivalent" found in the weathered sandstone from boring 17b are probably accounted for by calcite observable on fracture planes in this massive sandstone. Obviously most of the overburden at this location is relatively free from a net acid-producing potential and after burial of coal-roof shales, revegetation has not shown any toxic acidity problems.

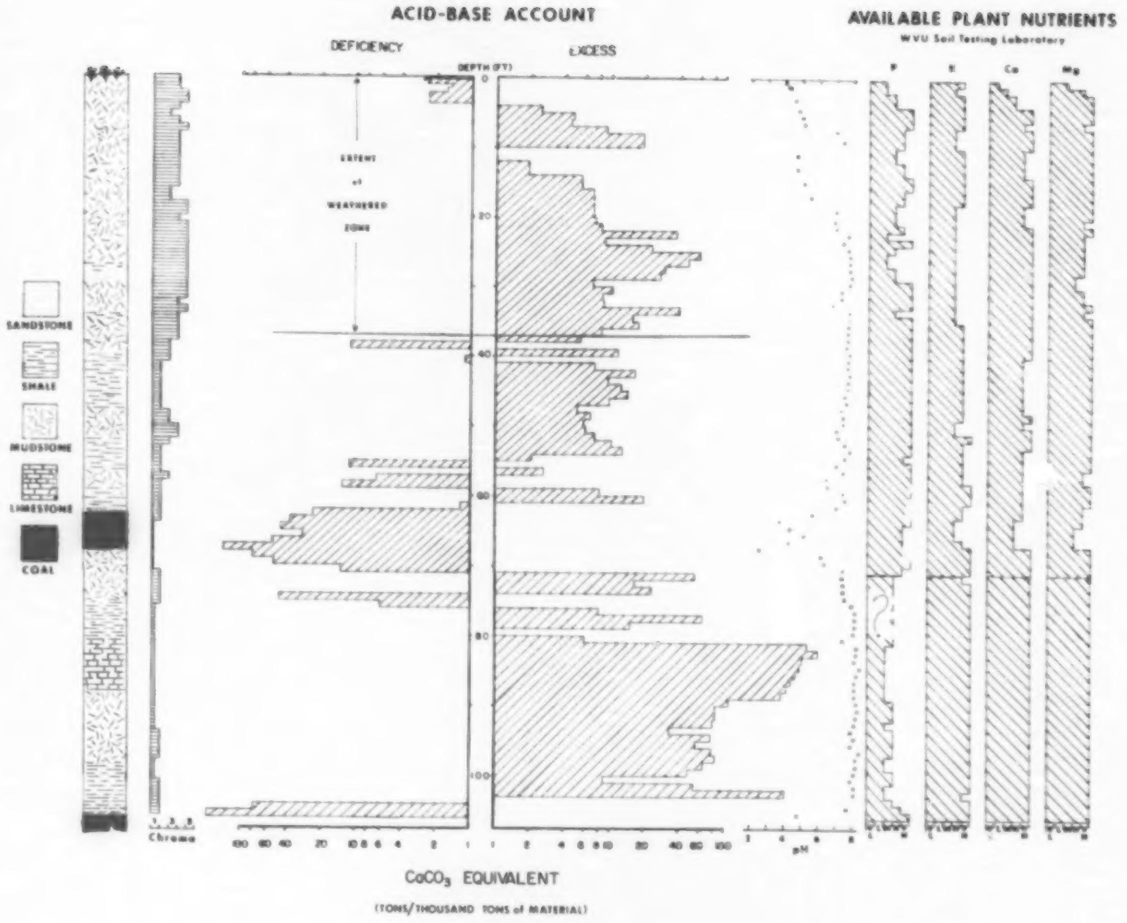


FIGURE 16. COMPOSITE OF DATA FROM SITES HH AND OO, SHOWING COMPREHENSIVE CHARACTERIZATION OF REDSTONE AND PITTSBURGH COAL OVERBURDEN AT ONE LOCALITY

Tables 8 through 12 illustrate overburden characteristics in one of the most heavily mined areas of the coal fields within this area of study. The predominating lime influence from calcareous shales and mudrocks, even beyond the recognized limestone in parts of the section, undoubtedly account for recent successful vegetative reclamation. Increasing pH of the long acidic Elk Creek watershed is probably due in part from erosion of calcareous materials exposed during surface mining. Data from Site HH and OO have been combined into an overall illustration of overburden characterization as Figure 16. The data plotted are drawn from Tables 8 and 9. The somewhat less than ideal quality of the original topsoil can be seen in most of the chemical measurements. The increased pH and Excess $CaCo_3$ Equivalent at about nine feet reflects the presence of a few feet of red shale in the section. Exhaustive evaluation of various properties of the "red beds" has not been completed, but it appears that no significant toxicity is associated with red shales and indeed most appear quite calcareous. Figure 16 shows the questionably high amounts of plant available phosphorus in the lower high-lime beds overlying the Pittsburgh coal. This is further discussed in Section VIII.

Sites A-A', 14 and A-A', 15 show continuing calcareous influence in Pittsburgh overburden, except for roof shale and underclay associated with the Redstone and Pittsburgh seams. Site A-A', 14 shows diminution in quality of the once thick Redstone limestone as we move southwest. Site A-A', 12 also shows variable quality of the limestone but a continued calcareous influence throughout the entire overburden section. Samples 4 and 5 of this site again show distinctive compositional features of the encroaching red beds. Although analyses of hand samples from abandoned mine areas south and west from Site A-A', 12, consistently verify the trends shown in Figure 7 (Section IV); lack of widespread active surface mining hindered the gathering of samples for detailed incremental study, and indeed as discussed in Section IV, extensive surface mining is not likely to occur in these areas.

Table 14 presents analyses of material overlying the Elk Lick coal seam, in the upper part of the Conemaugh Group. As seen from these data there is a small but consistent amount of calcareous material throughout this section, although not nearly as much as was seen in some other Province 3 samples. An interesting feature of this site is the weathered coal seam (sample +9) within the weathered rock zone, which is 19 feet thick.

SURFACE MINING PROVINCE 2

Figure 2 (Section IV) shows the geologic basis for designating Province 2 as extending from the Saltsburgh Sandstone (Lower Conemaugh) into the Pottsville Group. The largest variety of types of coal overburden materials are evident in this Province.

Site FF (Table 15) comprising overburden material at the top of the section representing Province 2, shows an Excess $CaCO_3$ Equivalent throughout much of the material, however for the first time there appears a deficiency of bases in the upper weathered zone which includes the original natural soil. This characteristic also signals the approach to the Pedologic Division (Figure 2) that has been drawn to illustrate changes in soil properties evident in parent materials as one descends the section. The somewhat more calcareous material (samples 4 and 5, boring FF-b, Table 16) between the Upper Bakerstown and Lower Bakerstown coals is characteristic of this section, although it is much more striking farther west, e.g. B-B', 13 of Figure 9, Section IV. Bakerstown coal overburden at Site T (Table 17) contains over 15 feet of material free from potential acid toxicity, including a stratum of impure limestone; however in this area the highly pyritic roof shale over the Bakerstown coal seam attains a thickness of up to 15 feet. The toxic nature of this black shale has been indicated by failures in trying to revegetate areas where this material has been placed on the spoil surface and where no significant attempt was made to amend or improve the area before planting. Obviously a favorable material for vegetation was available for placement on the spoil surface, and in more recent surface mine operations, good success in reclamation has been achieved through careful spoil placement of the overburden materials. Tables 18, 19, and 20 include analyses of Upper Freeport coal overburden at three sites in the northern part of Surface Mining Province 2.

Many of the barren spoils of northern West Virginia are composed of this potentially acid-forming material where it has remained exposed on the land surface after mining. Although occasional slightly calcareous zones can be found in this sandstone, the predominating influence is that of oxidizable pyrites. All these sites show a need for amendments even if material from the surficial weathered zone (20 to 25 ft. from the land surface) is replaced as topsoil. The highly leached natural soil found here also distinguishes the Pedologic division in parent material as discussed in Sections IV and V. The somewhat less acid toxic nature of overburden at Site AA is probably related to its position of nearer the central basin of the Upper Freeport seam in western Pennsylvania. The principals of gradational trends in overburden composition in the Monongahela Formation observed

Table 5

Sample characterization and Acid-Base Account of Pittsburgh coal overburden at Site A-A', 17a.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
18-20'[a]	17	0	10 YR 6/1	.260	8.12	9.07		0.95
20-22'	16	0	5 Y 6/1	.380	11.88	6.76	5.12	
22-24'	15	0	5 Y 6/1	.540	16.88	7.77	9.11	
24-26'	14	0	5 Y 6/1	1.070	33.44	15.18	18.26	
26-28'	13	0	10 YR 3/2	5.500	171.88	3.17	168.71	
28-30'	12	3	5 Y 6/1	1.675	52.34	222.79		170.45
30-32'	11	4	2.5 Y 6/2	.045	1.41	716.59		715.18
32-34'	10	4	2.5 Y 6/2	.025	0.78	833.45		832.67
34-36'	9	4	2.5 Y 6/3	.045	1.41	716.59		715.18
36-38'	8	4	2.5 Y 7.5/2	.130	4.06	855.72		851.66
38-40'	7	4	2.5 Y 7.5/2	.120	3.75	733.85		730.10
40-42'	6	4	10 YR 7/1	.620	19.38	562.57		543.19
42-44'	5	2	10 YR 7/1	1.200	37.50	55.43		17.93
44-46'	4	0	10 YR 7/1	.225	7.03	12.90		5.87
46-48'	3	0	10 YR 7/1	.100	3.12	6.76		3.64
48-50'	2	2	2.5 Y 6/1	.800	25.00	30.39		5.39
50-52'	1	0	2.5 Y 6/1	3.550	110.94	3.17	107.77	
52-	Pittsburgh coal seam							
	Coal	0	5 YR 2/1	8.550	267.19	-1.17	268.36	

---

[a] feet X 0.3048 = meters

Table 6

Sample characterization and Acid-Base Account of Pittsburgh coal overburden at Site A-A', 17b.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
3-4'	1 SS[b]	0	10 YR 6.5/4	.005	.16	1.04		0.98
4-5'	2 SS	0	10 YR 6.5/4	.008	.25	1.55		1.30
5-6'	3 SS	0	10 YR 6.5/3	.007	.22	2.57		2.35
6-7'	4 SS	0	10 YR 6.5/3	.005	.16	1.80		1.64
7-8'	5 SS	0	10 YR 7/3	.005	.16	2.06		1.90
8-9'	6 SS	0	10 YR 6.5/4	.006	.19	1.80		1.61
9-10'	7 SS	0	10 YR 6.5/4	.006	.19	2.06		1.87
10-11'	8 SS	0	10 YR 6.5/4	.004	.12	2.32		2.20
11-12'	9 SS	0	10 YR 6.5/3	.004	.12	-1.78	1.90	
12-13'	10 SS	0	10 YR 6.5/3	.004	.12	4.62		4.50
13-14'	11 SS	0	10 YR 6/4	.004	.12	2.83		2.71
14-15'	12 SS	0	10 YR 5.5/4	.009	.28	3.60		3.32
15-16'	13 MR	0	2.5 Y 5.5/2	.235	7.34	4.62	2.72	
16-17'	14 SH	0	2.5 Y 5.5/2	.460	14.38	3.85	10.53	
17-18'	15 SH	0	2.5 Y 5.5/2	.630	19.69	4.62	15.07	
18-19'	16 SH	0	2.5 Y 5.5/1	1.140	35.62	18.71	16.91	

[b]
SS = sandstone
SH = shale
MR = mudrock
LS = limestone
I = intercalate
C = coal

Table 7

Sample characterization and Acid-Base Account of Pittsburgh coal overburden at Site A-A', 17c.

Depth	(Sample #)	Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material: Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
26-27'	1	3	2.5 Y 5.5/0	2.575	70.47	301.84		231.37
	2	2	2.5 Y 7.5/0	1.500	46.88	50.34		3.46
	3	2	2.5 Y 7/0	1.290	40.41	61.58		21.17
	4	4	2.5 Y 7.5/0	.895	27.97	289.70		261.73
	5	5	2.5 Y 7.5/1	.260	7.12	644.92		637.80
	6	5	2.5 Y 7.5/1	.041	1.28	836.10		834.82
	7	5	2.5 Y 7/1	.085	2.66	703.65		700.99
	8	5	2.5 Y 7/1	.130	4.06	554.96		550.90
	9	5	N 7.5/0	.035	1.09	927.31		926.22
	10	5	10 YR 7.5/2	.035	1.09	817.35		816.26
	11	5	10 YR 7.5/2	.045	1.41	873.58		872.17
	12	5	10 YR 7.5/3	.022	.70	917.31		916.61
	13	5	10 YR 7.5/2	.025	.78	574.95		574.17
	14	5	2.5 Y 7/2	.070	2.19	672.41		670.22
40-41'	15	5	2.5 Y 7/1	.570	17.81	392.52		374.71

Table 8

Sample characterization and Acid-Base Account of Redstone coal overburden at Site HH.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
0-3"	soil[a]	0	10 YR 6/3	.029	0.91	0.13	0.78	
3-5"	soil	0	10 YR 6/3	.020	0.63	-2.04	2.67	
5-8"	soil	0	10 YR 7/3	.010	0.31	-2.03	2.34	
8-12"	soil	0	10 YR 7/3	.009	0.28	-2.17	2.45	
12-18"	soil	0	10 YR 7/3	.007	0.22	-1.28	1.50	
18-26"	soil	0	10 YR 7/3	.008	0.25	-1.40	1.65	
26-46"	soil	0	2.5 Y 7/4	.003	0.09	-2.30	2.39	
46-48"	soil	0	7.5 YR 6/4	.002	0.06	-0.13	0.19	
4-5'	MS	0	10 YR 6/3	.003	0.09	2.55		2.46
5-6'	MS	0	10 YR 7/2	.005	0.16	4.85		4.69
6-7'	MS	0	10 YR 6/3	.004	0.13	4.59		4.46
7-8'	MS	0	7.5 YR 6/4	.004	0.13	9.18		9.05
8-10'	MS	1	5 YR 6/3	.004	0.13	19.13		19.00
10-12'	MS	0	10 YR 7/3	.005	0.16	0.77		0.61
12-14'	MS	0	10 YR 6/3	.004	0.13	2.04		1.91
14-16'	MS	0	10 YR 6/3	.002	0.06	5.61		5.55
16-18'	MS	0	10 YR 7/2	.003	0.09	7.14		7.05
18-20'	MS	0	2.5 Y 7/4	.002	0.06	7.14		7.08
20-21'	1 MS	0	2.5 Y 7/3	.002	0.06	7.42		7.36
21-22'	2 MS	0	2.5 Y 7/4	.003	0.09	8.33		8.24
	3 MS	1	2.5 Y 6/4	.005	0.16	37.76		37.60
	4 MS	0	2.5 Y 6/4	.002	0.06	8.85		8.79
	5 MS	1	2.5 Y 7/4	.003	0.09	22.98		22.89
	6 MS	2	2.5 Y 7/4	.002	0.06	60.10		60.04
	7 MS	2	2.5 Y 7/4	.002	0.06	48.65		48.59

Table 8 (continued)

	8 SH	2	2.5 Y 7/4	.002	0.06	29.50		29.44
	9 SS	2	2.5 Y 6/4	.002	0.06	27.21		27.15
-30'	10 SS	0	2.5 Y 7/4	.002	0.06	7.04		6.98
	11 MS	0	2.5 Y 7/4	.003	0.09	10.56		10.47
	12 MS	0	2.5 Y 7/4	.001	0.03	8.49		8.46
	13 MS	0	2.5 Y 7/3	.001	0.03	8.77		8.74
	14 MS	2	2.5 Y 6/4	.002	0.06	39.80		39.74
	15 SH	1	5 Y 7/3	.001	0.03	15.45		15.42
	16 MS	0	5 Y 6/3	.004	0.13	17.65		17.42
	17 MS	0	5 Y 6/3	.013	0.41	8.77		8.36
	18 MS	0	5 Y 7/3	.156	4.88	10.30		5.42
	19 MS	0	5 Y 7/2	.650	20.31	9.15	11.16	
-40'	20 MS	0	5 Y 7/2	.425	13.28	24.99		11.71
	21 SH	0	5 Y 7/2	.615	19.22	18.11	1.11	
	22 SH	0	5 Y 6/1	.420	13.13	20.40		7.27
	23 SH	0	5 Y 6/1	.290	9.06	25.30		16.24
	24 SH	0	5 Y 5/1	.295	9.22	18.74		9.52
	25 SH	0	5 Y 6/1	.140	4.38	16.65		12.27
	26 SH	0	5 Y 6/1	.130	4.06	18.11		14.04
	27 SH	0	5 Y 6/1	.105	3.28	12.95		9.67
	28 SH	0	2.5 Y 5/1	.145	4.53	9.61		5.08
	29 MS	0	2.5 Y 6/2	.100	3.13	9.87		6.74
-50'	30 MS	0	2.5 Y 5.5/2	.080	2.50	8.34		5.84
	31 MS	0	2.5 Y 6/3	.035	1.09	7.17		6.08
	32 MS	0	2.5 Y 6/3	.025	0.78	8.08		7.30
	33 SH	0	2.5 Y 5/2	.080	2.50	12.55		10.05
	34 SH	0	5 Y 5.5/1	.200	6.25	18.84		12.59
	35 SH	0	10 YR 5.5/1	.500	15.63	17.67		2.04
	36 SH	0	5 Y 5.5/1	.800	25.00	13.59	11.41	
	37 SH	0	5 Y 6/1	.360	11.25	13.85		2.60
	38 MS	0	2.5 Y 5/2	.400	12.50	5.89	6.61	
	39 MS	0	2.5 Y 5/1	.755	23.59	10.51	13.08	

Table 8 (continued)

-60'	40	SH	0	5 Y 4.5/1	.420	13.13	21.01		7.88
	41	SH	0	5 Y 4.5/1	.350	10.94	30.50		19.56
	42	SH	0	5 Y 4.5/1	.760	23.95	22.54	1.21	
	43	SH	0	5 Y 4/1	1.050	32.81	9.23	23.58	
	44	C	0	5 Y 3.5/1	1.250	39.06	2.83	36.23	
	45	C	0	2.5 Y 2/0	1.450	45.31	0.77	44.54	
	46	C	0	2.5 Y 2/0	1.025	32.03	2.58	29.45	
	47	C	0	2.5 Y 2/0	1.725	53.91	1.28	52.63	
	48	C	0	2.5 Y 3.5/0	4.675	146.09	4.11	141.98	
	49	MS	1	N 6.5/0	3.150	98.44	20.25	78.19	
-70'	50	MS	1	N 6.5/0	2.300	71.88	20.25	51.63	
	51	MS	1	N 7/0	1.410	44.06	30.75	13.31	

[a] Soil = soil
SS = sandstone
SH = shale
MS = mudstone
C = coal

Table 9

Sample characterization and Acid-Base Account of Pittsburgh coal overburden at Site OO.

Depth	(Sample #)	Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
					Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
	1 MS	2	2.5 Y 7/1	.385	12.03	67.06		55.03
	2	2	2.5 Y 6.5/1	1.43	44.69	60.97		16.28
	3	2	2.5 Y 6.5/1	1.90	59.38	82.75		23.37
	4 ↓	0	2.5 Y 7/1	1.77	55.31	9.97	45.34	
	5 SH	1	2.5 Y 7/1	1.12	35.00	28.97	6.03	
	6	1	2.5 Y 7/0	.665	20.78	28.71		7.93
	7 LS	2	2.5 Y 7/0	.445	13.91	77.95		64.04
	8	1	2.5 Y 7.5/0	.450	14.06	28.97		14.91
	9	1	2.5 Y 7/0	.855	26.72	26.19	0.53	
	10	2	2.5 Y 7/0	1.87	58.44	64.44		6.00
	11	4	2.5 Y 7/0	.690	21.56	551.42		529.86
	12	5	2.5 Y 7.5/0	.335	10.47	671.05		660.58
	13	5	2.5 Y 7/0	.510	15.94	495.56		479.62
	14	5	2.5 Y 7/0	.385	12.03	467.12		455.09
	15	5	2.5 Y 7/0	.695	21.72	439.92		418.20
	16 ↓	5	2.5 Y 7/0	.835	26.09	411.60		385.51
	17 MS	4	2.5 Y 7/0	.215	6.72	355.96		349.24
	18	4	2.5 Y 7/0	.550	17.19	332.48		315.29
	19	1	2.5 Y 7/0	.315	9.84	119.42		109.58
	20	1	2.5 Y 7/0	.215	6.72	89.63		82.91
	21	1	2.5 Y 7/0	.080	2.50	85.58		83.08
	22	1	2.5 Y 7/0	.095	2.97	82.31		79.34
	23	1	2.5 Y 7/0	.100	3.12	36.62		33.50
	24 ↓	1	2.5 Y 7/1	.055	1.72	78.03		76.31

Table 9 (continued)

25		1	2.5 Y 7/1	.050	1.56	57.32		55.76
26	MS	1	2.5 Y 7/1	.040	1.25	78.51		77.26
27		1	2.5 Y 7/1	.045	1.41	85.09		83.68
28	↓	1	2.5 Y 7/0	.070	2.19	67.42		65.23
29	SH	1	2.5 Y 7/0	.360	11.25	59.59		48.34
30		1	2.5 Y 6/0	1.69	52.81	61.61		8.80
31		1	2.5 Y 6/1	.780	24.38	78.51		54.13
32		3	2.5 Y 6.5/1	1.59	49.69	391.88		342.19
33	No Sample							
34		1	2.5 Y 5.5/1	3.50	109.38	32.00	77.38	
35	↓	0	2.5 Y 4.5/1	6.72	210.00	13.77	196.23	
	Coal (Pittsburgh)							

Table 10

Sample characterization and Acid-Base Account of Pittsburgh coal overburden at Site A-A', 14a.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
	Redstone coal seam							
	1	0	N 6/	2.250	70.31	5.85	64.46	
	2	0	N 7/	1.240	38.75	8.35	30.40	
	3	0	N 7/	.905	28.28	10.54	17.74	
	4	0	N 7/	.700	21.86	11.95	9.91	
	5	0	5 Y 7/1	.760	23.75	32.32		8.57
	6	2	5 Y 7/1	.710	22.19	94.43		72.24
	7	2	5 Y 7/1	.800	25.00	105.69		80.69
	8	2	N 7/	.630	19.69	84.19		64.50
	9	1	N 7/	.600	18.75	32.90		14.15
	10	0	N 7/	.430	13.44	17.93		4.49
	11	0	10 YR 7/	.260	8.13	15.81		7.68
	12	3	2.5 Y 7/0	.140	4.38	94.12		89.74
	13	2	N 7/	.110	3.44	47.69		44.25
	14	2	10 YR 7/1	.050	1.56	51.17		49.61
	15	0	10 YR 7/1	.065	2.03	14.98		12.95
	16	0	10 YR 7/1	.140	4.38	10.70		6.32
	17	1	5 Y 6/1	.060	1.88	24.61		22.73
	18	0	5 Y 6/1	.030	0.94	14.85		13.91
	19	0	10 YR 7/1	.070	2.19	13.45		11.26
	20	1	10 YR 7/1	.020	0.63	29.90		29.27
	21	0	10 YR 7/1	.020	0.63	21.86		21.23
	22	2	10 YR 7/1	.110	3.44	44.15		40.71
	23	2	10 YR 6/1	.275	8.59	49.40		40.81
	24	0	10 YR 6/1	.120	3.75	20.26		16.51

Table 10 (continued)

25	0	5 Y 5/1	.125	3.91	9.42		5.51
26	0	5 Y 4/1	1.225	38.28	9.11	29.17	
Pittsburgh coal seam							

Table 11

Sample characterization and Acid-Base Account of Pittsburgh coal overburden at Site A-A', 14b.

Depth (Sample #)	Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
Redstone coal seam							
1	0	5 Y 6/1	1.425	44.53	13.84	30.59	
2	1	7.5 YR 7/0	1.390	43.44	12.19	31.25	
3	0	7.5 YR 7/0	1.250	39.06	9.65	29.41	
4	0	2.5 Y 7.5/0	.735	22.97	14.86	8.11	
5	0	2.5 Y 8/0	.645	20.16	9.27	10.89	
6	1	2.5 Y 7.5/0	.630	19.69	18.79	0.90	
7	2	5 Y 7/1	.805	25.16	36.01		10.85
8	3	2.5 Y 8/0	.620	19.38	123.80		104.42
9	2	5 Y 7.5/1	.525	16.41	99.20		82.79
10	2	5 Y 7/1	.645	20.16	56.64		36.48
11	1	5 Y 7/1	.480	15.00	31.26		16.26
12	1	10 YR 7/1	.350	10.94	21.06		10.12
13	2	7.5 YR 7.5/0	.245	7.66	41.13		33.47
14	2	10 YR 7.5/0	.165	5.16	54.60		49.44
15	2	7.5 Y 7.5/0	.085	2.66	42.65		39.99
16	1	5 Y 7/1	.055	1.72	27.11		25.39
17	1	5 Y 7.5/1	.030	.94	24.40		23.46
18	1	10 YR 7/1	.050	1.56	20.40		18.84
19	2	10 YR 7.5/1	.050	1.56	56.21		54.95
20	2	10 YR 7.5/1	.030	.94	39.55		38.61
21	2	10 YR 7/1	.015	.47	59.21		58.74
22	2	10 YR 7/1	.020	.63	52.91		52.28
23	2	10 YR 6.5/1	.020	.63	53.58		52.95
24	2	10 YR 6.5/1	.065	2.03	58.83		56.80
25	2	10 YR 6.5/1	.280	8.75	41.97		33.22

Table 11 (continued)

26	1	10 YR 6.5/1	.190	5.94	22.72		16.78
27	1	10 YR 6.5/1	.270	8.44	22.21		13.77
28	0	10 YR 6/1	.510	15.94	10.91	5.03	
29	0	10 YR 5.5/1	1.750	54.69	6.27	48.42	
30	0	10 YR 3/1	1.925	60.16	10.63	49.53	
Pittsburgh coal seam							

Table 12

Sample characterization and Acid-Base Account of Pittsburgh coal overburden at Site A-A', 15.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
	Redstone coal seam							
52-53'	1	0	7.5 YR 5/0	1.730	54.06	8.76	45.30	
	2	1	2.5 Y 7/0	.760	23.75	17.22	6.53	
	3	1	2.5 Y 7/0	.545	17.03	18.76		1.73
	4	2	N 7/	.820	25.63	108.54		82.91
	5	2	N 7/	.555	17.34	99.97		82.63
	6	1	N 7/	.380	11.88	31.01		19.13
	7	1	N 7/	.340	10.63	40.09		29.46
	8	2	N 7/	.350	10.94	41.71		30.77
	9	2	N 7/	.230	7.19	33.60		26.41
-60'	10	1	N 7/	.290	9.06	28.54		19.48
	11	0	N 7/	.310	9.69	11.80		2.11
	12	0	N 7/	.260	8.13	8.03	.10	
	13	3	5 Y 6/1	.555	17.34	114.83		97.49
	14	4	5 Y 6/1	.420	13.13	238.08		224.95
	15	5	N 7/	.305	9.53	443.92		434.39
	16	5	10 YR 7/1	.285	8.91	572.88		563.97
	17	5	10 YR 7/1	.320	10.00	582.30		572.30
	18	5	10 YR 7/1	.375	11.72	577.84		566.12
	19	2	10 YR 7/1	.115	3.59	90.00		86.41
-70'	20	0	5 Y 6/1	.065	2.03	12.98		10.95
	21	3	5 Y 7/1	.195	6.09	118.35		112.26
	22	2	10 YR 7/1	.410	12.81	34.38		21.57
	23	2	5 Y 6/1	1.340	41.88	46.20		4.32
	24	3	5 Y 6/1	3.125	97.66	161.67		64.01
	25	2	5 Y 6/1	4.000	125.00	27.73	97.27	

Table 12 (continued)

	26	3	5 Y 5/1	2.225	69.53	74.57		5.04
	27	0	5 Y 5/1	1.875	58.59	3.31	55.28	
80-81'	28	0		6.250	195.31	1.36	193.95	
	Pittsburgh coal seam							

Table 13

Sample characterization and Acid-Base Account of Redstone and Pittsburgh coal overburden at Site A-A', 12.

Depth	(Sample #)	Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
					Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
18.0' -	1 MR	1	2.5 Y 7/0	.003	.09	23.51		23.42
- 22.9'	2 MR	0	2.5 Y 7/0	.002	.06	9.65		9.59
22.9' - 24.8'	3 MR	2	2.5 Y 7/0	.016	.50	78.46		77.96
24.8' -	4 MR	3	5 YR 6/2	.017	.53	184.98		184.45
- 27.5'	5 MR	0	5 YR 6/3	.002	.06	23.51		23.45
27.5' - 34.5'	6 SS	0	2.5 Y 7/0	.003	.09	13.12		13.03
34.5' - 35.8'	7 SH	0	2.5 Y 7/0	.008	.25	11.38		11.13
35.8' - 39.0'	8 SS	1	2.5 Y 7/0	.007	.22	13.12		12.90
39.0' - 39.8'	9 MR	1	5 Y 7/1	.003	.09	24.50		24.41
39.8' - 44.0'	10 SS	0	2.5 Y 7/0	.007	.22	20.54		20.32
44.0' -	11 SH	0	5 Y 7/1	.007	.22	11.39		11.17
	12 SH	0	2.5 Y 7/0	.035	1.09	8.66		7.57
	13 MR	0	2.5 Y 7/0	.630	19.69	8.91	10.78	
	14 MR	0	2.5 Y 7/0	.615	19.22	15.35	3.87	
	15 MR	0	2.5 Y 7/0	.420	13.12	13.37		.25
	16 MR	0	2.5 Y 7/0	.090	2.81	16.58		13.77
	17 MR	1	2.5 Y 7/0	.200	6.25	36.88		30.63
	18 MR	1	2.5 Y 7/0	1.500	46.88	28.71	18.17	
- 63.0'	19 MR	2	5 Y 7/1	.190	5.94	70.04		64.10
63.0' - 66.3'	20 SS	0	2.5 Y 7/0	.130	4.06	11.63		7.57
66.3' - 69.3'	21 SH	0	2.5 Y 7/0	.305	9.53	23.39		13.86
69.3' - 73.7'	22 I	2	2.5 Y 7/0	.030	.94	94.32		93.38
73.7' - 75.7'	23 SH	2	2.5 Y 7/0	.030	.94	48.26		47.32

Table 13 (continued)

75.7' -	24 SH	1	2.5 Y 7/0	.011	.34	29.55		29.21
- 90.0'	25 I	1	2.5 Y 7/0	.065	2.03	28.34		26.31
90.0' -	26 MR	0	2.5 Y 7/0	.010	.31	25.86		25.55
	27 SH	0	2.5 Y 7/0	.007	.22	17.97		19.75
- 99.0'	28 SH	0	2.5 Y 7/0	.010	.31	39.30		38.99
99.0' -104.0'	29 MR	0	2.5 Y 7/0	.012	.38	27.82		27.44
104.0'-106.1'	30 MR	0	2.5 Y 7/0	.005	.16	20.44		20.28
106.1'-108.8'	31 MR	1	2.5 Y 7/0	.085	2.66	21.43		18.77
109.6'-	32 MR	2	2.5 Y 7/0	.075	2.34	82.66		80.32
	33 MR	4	7.5 YR 6/2	.019	.59	159.38		158.79
-118.0'	34 MR	2	2.5 Y 7/0	.150	4.69	126.86		122.17
118.0'-	35 SH	0	2.5 Y 7.5/0	.040	1.25	18.22		16.97
-131.5'	36 MR	0	2.5 Y 7.5/0	.012	.38	10.10		9.72
131.5'-	37 SH	0	2.5 Y 7.5/0	.075	2.34	15.77		13.43
	38 SH	0	2.5 Y 7.5/0	.006	.19	9.85		9.66
-142.0'	39 MR	2	2.5 Y 7.5/0	.340	10.62	292.19		281.57
142.0'-144.5'	40 SH	0	2.5 Y 7.5/0	.025	.78	12.57		11.79
144.5'-	41 MR	0	10 YR 6/1	.045	1.41	28.07		26.66
	42 MR	0	10 YR 6/1	.350	10.94	18.71		7.77
	43 I	0	10 YR 6/1	.125	3.91	18.46		14.55
-157.9'	44 I	0	10 YR 6/1	.260	8.12	11.09		2.97
164.7'-	45 SH	0	2.5 Y 7/0	.250	7.81	21.19		13.38
-171.5'	46 SH	0	2.5 Y 7.5/01	.025	32.03	13.79	18.24	
171.5'-175.5'	47 I	2	2.5 Y 7.5/0	.745	23.28	353.18		329.90
175.5'-178.5'	48 I	0	2.5 Y 7.5/0	.100	3.12	17.97		14.85
178.5'-	49 LS	4	2.5 Y 7.5/0	.135	4.22	531.25		527.03
	50 SH	2	2.5 Y 7.5/0	.030	.94	306.00		305.06
	51 MR	2	2.5 Y 7.5/0	.030	.94	164.26		163.32
-189.3'	52 LS	2	2.5 Y 8/0	.070	2.19	407.26		405.07
189.3'-190.8'	53 MR	1	2.5 Y 8/0	.029	.91	34.72		33.81
190.8'-192.3'	54 MR	2	2.5 Y 8/0	.060	1.88	119.96		118.08
192.5'-	55 MR	2	N 7/0	.040	1.25	67.72		66.47
-199.0'	56 MR	0	10 YR 6/1	.040	1.25	8.37		7.12
199.0'-200.0'	57 I	0	10 YR 6/1	.013	.41	10.84		10.43

Table 14

Sample characterization and Acid-Base Account of Elk Lick coal overburden at Site PP.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
0-3"	A Hor.	0	10 YR 2/3	.065	2.03	2.02	.01	
0-1'	A & B Hor.	0	2.5 Y 7/4	.010	0.31	-2.00	2.31	
1-2'	B Hor.	0	2.5 Y 7/4	.006	0.19	-0.24	0.43	
2-3'	B_2 & B_3 Hor.	0	2.5 Y 7/4	.005	0.16	2.77		2.61
3-4'	+17	0	2.5 Y 5.5/3	.005	0.16	4.03		3.87
4-5'	+16	0	2.5 Y 5.5/3	.003	0.09	2.52		2.43
5-6'	+15	0	2.5 Y 6/3	.012	0.38	6.54		6.16
6-7'	+14	0	2.5 Y 6/3	.003	0.09	5.03		4.94
7-8'	+13	0	2.5 Y 6/3	.001	0.03	4.53		4.50
8-9'	+12	0	2.5 Y 5/2	.003	0.09	7.30		7.21
9-10'	+11	0	2.5 Y 3.5/1	.040	1.25	6.04		4.79
10-11'	+10	0	2.5 Y 4.5/1	.040	1.25	9.05		7.80
11-12'	+ 9	0	5 YR 2/1	3.85	120.31	0.77	119.54	
12-13'	+ 8	0	2.5 Y 7.5/3	.075	2.34	5.29		2.95
13-14'	+ 7	0	2.5 Y 7/2	.008	0.25	7.30		7.05
14-15'	+ 6	0	2.5 Y 7/2	.001	0.03	7.30		7.27
15-16'	+ 5	0	2.5 Y 7/3	.003	0.09	6.54		6.45
16-17'	+ 4	0	10 YR 6/5	.004	0.12	7.04		6.92
17-18'	+ 3	0	10 YR 6/5	.003	0.09	7.80		7.71
18-18.5'	+ 2	0	10 YR 6/6	.003	0.09	7.55		7.46
18.5-19'	+ 1	0	5 Y 6.5/3	.005	0.16	42.47		42.31
19-20'	1	1	2.5 Y 6/3	.085	2.66	12.82		10.16
	2	1	2.5 Y 7/1	.345	10.78	31.91		21.13

Table 14 (continued)

19-20'	3	1	2.5 Y 7/3	.155	4.84	6.54		1.70
	4	1	2.5 Y 7/3	.105	3.28	4.03		0.75
	5	1	2.5 Y 7/3	.020	0.62	12.57		11.95
	6	1	2.5 Y 6.5/3	.055	1.72	17.59		15.87
	7	1	2.5 Y 6.5/3	.016	0.50	15.84		15.34
	8	2	2.5 Y 7/3	.055	1.72	24.14		22.42
	9	3	2.5 Y 7/2	.280	8.75	38.22		29.47
	10	1	2.5 Y 7/2	.235	7.34	11.31		3.97
	11	1	2.5 Y 7/3	.270	8.44	6.29	2.15	
	12	2	10 YR 7/5	.325	10.16	45.23		35.07
	13	2	2.5 Y 7/2	.240	7.50	23.63		16.13
	14	1	2.5 Y 7.5/1	.210	6.56	18.35		11.79
	15	1	2.5 Y 7.5/2	.080	2.50	15.84		13.34
	16	1	5 Y 7.5/2	.065	2.03	17.09		15.06
	17	1	2.5 Y 7.5/2	.025	0.78	10.56		9.78
	18	1	2.5 Y 7/3	.016	0.50	18.10		17.60
	19	1	2.5 Y 7/3	.030	0.94	23.37		22.43
	20	1	2.5 Y 7/2	.065	2.03	31.66		29.63
	21	1	2.5 Y 7.5/2	.065	2.03	34.42		32.39
	22	1	2.5 Y 7/2	.105	3.28	11.57		8.29
	23	1	2.5 Y 7/3	.045	1.41	15.84		14.43
	24	1	2.5 Y 7/3	.090	2.81	18.10		15.29
	25	1	2.5 Y 7/1	.280	8.75	34.67		25.92
	26	1	5 Y 7/1	.455	14.22	36.43		22.21
	27	0	2.5 Y 7/2	3.22	100.62	7.80	92.82	
	28	0	10 YR 7/1	.050	1.56	3.53		1.97
	29	0	2.5 Y 7/1	.290	9.06	2.52	6.54	
	30	0	2.5 Y 7.5/1	.500	15.62	2.52	13.10	
	31	0	2.5 Y 6/1	.380	11.88	1.52	10.36	
	32	0	2.5 Y 6/1	.340	10.62	3.28	7.34	
	33	0	2.5 Y 5.5/1	.405	12.66	3.28	9.38	
	34	0	2.5 Y 5.5/1	.160	5.00	1.52	3.48	

Table 14 (continued)

	35	2	10 YR 4.5/1	1.42	44.38	57.79		13.41
	36	3	2.5 Y 6/1	.710	22.19	174.61		152.42
	37	3	10 YR 6.5/1	.650	20.31	95.24		74.93
	38	1	10 YR 6/1	.520	16.25	22.87		6.62
	39	0	10 YR 5.5/1	.570	17.81	6.54	11.27	
58-59'	40	0	10 YR 3/1	2.10	65.62	4.53	61.09	

(Includes top 6" of coal)

Table 15

Sample characterization and Acid-Base Account of Upper Bakerstown coal overburden at Site FF.

Depth	(Sample #)	Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material: Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
0-4"	A, 0-4"	0	10 YR 4.5/3	.065	2.03	4.53		2.50
	B, 4-16"	0	2.5 Y 7.5/4	.016	0.50	-1.75	2.25	
	B, 16-26"	0	2.5 Y 7/4	.016	0.50	-2.50	3.00	
	C, 26-36"	0	2.5 Y 7/3	.007	0.22	-1.75	1.97	
15" increments	1	0	10 YR 7/5	.017	0.53	-2.50	3.03	
	2	0	10 YR 7/5	.007	0.22	-2.50	2.72	
	3	0	10 YR 7/5	.010	0.31	-2.75	3.06	
	4	0	2.5 Y 7/4	.012	0.38	-1.50	1.88	
	5	0	2.5 Y 7/5	.006	0.19	-1.75	1.94	
	6	0	2.5 Y 6.5/5	.017	0.53	0.26	0.27	
	7	0	2.5 Y 7.5/5	.006	0.19	1.02		0.83
	8	0	2.5 Y 6/5	.010	0.31	-0.24	0.55	
	9	0	2.5 Y 6.5/3	.010	0.31	0.51		0.20
	10	0	2.5 Y 6.5/4	.003	0.09	2.27		2.18
	11	0	5 Y 6.5/3	.005	0.16	4.03		3.87
	12	0	5 Y 6.5/1	.330	10.31	3.78	6.53	
	13	0	5 Y 6.5/1.5	.030	0.94	5.79		4.85
	14	0	5 Y 6/1	.045	1.41	5.79		4.38
	15	0	2.5 Y 6.5/0	.220	6.88	8.80		1.92
	16	1	2.5 Y 6.5/2	.135	4.22	20.10		15.88
	17	1	2.5 Y 6/2	.095	2.97	12.07		9.10
	18	1	2.5 Y 6/2	.060	1.88	12.07		10.19
	19	2	2.5 Y 6.5/3	.165	5.16	25.64		20.48
	20	1	2.5 Y 7.5/1	.325	10.16	27.64		17.48

Table 15 (continued)

	21	1	2.5 Y 7.5/1	.725	22.66	30.40		7.74
	22	1	2.5 Y 7.5/1	1.54	48.12	36.93	11.19	
	23	0	2.5 Y 7.5/0	.855	26.72	13.83	12.89	
	24	1	2.5 Y 7/1	.840	26.25	28.14		1.89
	25	1	2.5 Y 7.5/1	.955	29.84	39.19		9.35
	26	1	2.5 Y 6/0	.905	28.28	35.70		7.42
	27	1	2.5 Y 6.5/0	.875	27.34	33.67		6.33
	28	0	2.5 Y 5.5/1	1.64	51.25	13.34	37.91	
	29	0	2.5 Y 6/1	.270	0.44	15.33		6.89
	30	0	2.5 Y 6/1	.220	6.88	5.79	1.09	
38.1-39.37'	31	0	10 YR 2/1	3.02	94.38	1.27		93.11

Table 16

Sample characterization and Acid-Base Account of Lower Bakerstown coal overburden at Site FF-b.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
33.7-34.7'	1 C	0	2.5 Y 2/0	2.45	76.56	2.97	73.59	
34.7-35.8'	2 C	0	2.5 Y 2/0	1.98	61.88	2.72	59.16	
35.8-37.3'	3 C	0	2.5 Y 2/0	1.75	54.69	3.71	50.98	
37.3-	4 MS	2	2.5 Y 6.5/0	.380	11.88	77.96		66.08
-41.5'	5 MS	1	2.5 Y 7/0	.175	5.47	30.94		25.47
41.5-	6 SS	0	2.5 Y 6.5/0	.050	1.56	6.93		5.37
-55.5'	7 SS	0	2.5 Y 6.5/0	.085	2.66	6.93		4.27
55.5-56.3'	8 SH	0	2.5 Y 6.5/0	.025	0.78	5.20		4.42
56.3-57.9'	9 C	0	2.5 Y 2/0	3.40	106.25	0	106.25	
57.9-58.3'	10 SH	0	10 YR 2/1	5.20	162.50	1.24	161.26	
58.3-60.4'	11 C	0	2.5 Y 2/0	2.95	92.19	0.50	91.69	

Table 17

Sample characterization and Acid-Base Account of Bakerstown coal overburden at Site T (Project 14010EJE).

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
0-1'	+13	0	2.5 Y 7/4	.032	1.00	-0.73	1.73	
	+12	0	2.5 Y 7/4	.028	.88	0.40	.48	
	+11	0	2.5 Y 8/4	.016	.50	-0.86	1.36	
	+10	0	2.5 Y 7/4	.018	.56	-0.71	1.27	
Shale or mudrock throughout	+ 9	0	2.5 Y 8/4	.023	.72	-0.48	1.30	
	+ 8	0	2.5 Y 7/4	.005	.16			
	+ 7	0	2.5 Y 7/4	.018	.56	2.50		1.94
	+ 6	0	2.5 Y 7/4	.006	.18	4.24		4.06
	+ 5	0	2.5 Y 7.6	.019	.59	2.73		2.14
	+ 4	0	2.5 Y 7/4	.085	2.66	6.77		4.11
	+ 3	0	2.5 Y 7/4	.019	.59	4.24		3.65
	+ 2	0	5 Y 8/3	.015	.46	6.49		6.03
	+ 1	4	2.5 Y 7/2	.430	13.44	417.94		404.50
	+ 0	0	N 7/0	.165	5.16	15.93		10.77
	1	1	5 Y 7/3	.170	5.31	37.57		32.26
	2	2	5 Y 7/3	.255	7.96	86.08		78.12
	3	3	5 Y 7/2	.320	10.00	83.41		73.41
	4	1	5 Y 7/0	.385	12.03	36.08		24.05
	5	1	5 Y 7/1	.120	3.75	17.17		13.42
	6	1	2.5 Y 8/0	.145	4.53	65.30		60.77
	7	2	2.5 YR 7/0	.055	1.72	68.68		67.16
	8	1	2.5 Y 7/0	.035	1.09	16.44		15.35
	9	0	2.5 Y 7/0	.075	2.34	13.46		11.12
	10	0	2.5 Y 7/0	.415	12.96	10.71	2.25	
	11	-	-	.195	6.09	-	-	-

Table 17 (continued)

	12	0	2.5 Y 7/0	1.02	31.88	8.71	23.17	
	13	-	-	2.35	73.44	-	-	-
	14	-	-	1.87	58.44	-	-	-
	15	0	7.5 YR 6/0	1.52	47.50	20.65	26.85	
	16	0	2.5 Y 6/0	1.32	41.25	18.91	22.34	
	17	0	2.5 Y 6/0	1.83	57.18	14.92	42.26	
	18	0	2.5 Y 5/0	2.98	93.12	13.94	79.18	
	19	0	2.5 Y 4/0	2.60	81.25	17.68	63.57	
	20	0	2.5 Y 2/0	5.73	179.06	2.25	176.81	
	21	0	2.5 Y 2/0	3.70	115.62	-2.22	117.84	
	22	0	2.5 Y 3/0	5.20	162.50	-7.20	169.70	
	23	0	2.5 Y 3/0	4.15	129.68	-6.71	136.39	
-38'	24	0	2.5 Y 3/0	3.63	113.44	-6.94	120.38	
38-39'	-							
39-40'	-							
40-	Bakerstown coal seam							

Table 18

Sample characterization and Acid-Base Account of Upper Freeport coal overburden at Site AA.

Depth	(Sample #)	Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material: Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
0-1'	1	0	10 YR 6.3	.043	1.34	4.28		2.94
2'	2	0	10 YR 7/4	.026	0.81	-0.76	1.57	
3'	3	0	2.5 Y 7/6	.013	0.40	-0.76	1.17	
4'								
5'	5	0	2.5 Y 8/6	.035	1.09	-2.01	3.10	
6'	6	0	10 YR 8/6	.038	1.18	-1.76	2.95	
7'	7	0	10 YR 8/2	.028	0.88	-1.25	2.31	
8'	8	0	2.5 Y 8/2	.029	0.90	-2.27	3.18	
9'	9	0	2.5 Y 8/4	.011	0.34	-1.25	1.59	
10'	10	0	2.5 Y 7/4	.010	0.31	-0.76	1.07	
11'	11	0	2.5 Y 8/4	.009	0.28	-0.99	1.27	
12'	12	0	10 YR 8/3	.010	0.31	-0.99	1.30	
13'	13	0	10 YR 7/4	.007	0.22	-0.25	0.47	
14'	14	0	10 YR 7/4	.007	0.22	0.0	0.22	
15'	15	0	10 YR 7/4	.008	0.25	0.0	0.25	
16'	16	0	10 YR 7/4	.010	0.31	-0.26	0.57	
17'	17	0	10 YR 7/3	.008	0.25	0.0	0.25	
18'	18	0	10 YR 8/3	.010	0.31	-0.26	0.57	
19'	19	0	10 YR 8/3	.014	0.44	0.0	0.44	
20'	20	0	10 YR 7/3	.010	0.31	-0.26	0.57	
21'	21	0	10 YR 7/2	.160	5.00	-0.99	5.99	
22'	22	0	5 Y 7/1	.085	2.66	-2.27	4.93	
23'	23	0	N 7/0	.315	9.84	-0.76	10.60	
24'	24	0	10 YR 7/1	.490	15.31	0.25	15.56	
25'	25	1	10 YR 7/1	.165	5.16	22.72		17.56
26'	26	1	10 YR 7/1	.095	2.96	82.31		79.34

Table 18 (continued)

27'	27	2	10 YR 7/1	.160	5.00	100.98		95.98
28'	28	1	10 YR 7/1	.295	9.22	107.30		98.08
29'	29	0	10 YR 7/1	.065	2.03	37.13		35.10
30'	30	0	2.5 Y 8/0	.020	0.62	4.54		3.92
31'	31	0	10 YR 7/1	.015	0.46	6.83		6.36
32'	32	0	10 YR 7/1	.020	0.62	14.64		14.02
33'	33	0	10 YR 7/1	.025	0.78	22.26		21.48
34'	34	0	10 YR 7/1	.020	0.62	14.64		14.02
35'	35	0	10 YR 7/1	.030	0.94	10.35		9.41
36'	36	1	N 7/0	.050	1.56	61.86		60.30
37'	37	2	N 7/0	.105	3.28	49.75		46.47
38'	38	1	N 7/0	.065	2.03	18.18		16.15
39'	39	1	N 7/0	.340	10.62	29.04		18.42
40'	40	1	N 7/0	.150	4.68			5.41
41'	41	1	10 YR 7/1	.235	7.34			2.76
42'	42	1	N 7/0	.625	19.53	15.15	4.38	
43'	43	2	10 YR 7/1	.265	8.28	75.25		66.97
44'	44	1	N 7/0	.115	3.59			12.07
45'	45	1	N 7/0	.055	1.72	19.20		17.48
46'	46	1	5 Y 7/1	.025	0.78	22.47		21.69
47'	47	1	5 Y 7/1	.055	1.72	23.74		22.02
48'	48	1	5 Y 7/1	.085	2.66	19.43		16.77
49'	49	2	5 Y 7/1	.175	5.46	43.94		38.47
50'	50	1	5 Y 7/1	.480	15.00	26.52		11.52
51'	51	1	5 Y 7/1	.850	26.56	38.38		11.82
52'	52	1	5 Y 7/1	1.29	40.31	19.43	20.88	
53'	53	1	5 Y 7/1	.460	14.38	22.72		8.34
54'	54	2	N 7/0	.250	7.81	49.24		41.43
55'	55	1	N 7/0	.440	13.75	12.11	1.64	
56'	56	0	N 7/0	.255	7.96	18.44		10.47
57'	57	0	10 YR 6/1	.360	11.25	20.27		9.02
58'	58	0	10 YR 6/1	.450	14.06	14.64		0.60
59'	59	0	10 YR 4/1	.800	25.00	3.80	21.20	
59–64'	Upper Freeport coal		2.5 Y 2/0	2.50	78.12	-3.52	81.64	
64–67'		0	2.5 Y 6/1	2.82	88.12	-2.78	90.90	

Table 19

Sample characterization and Acid-Base Account of Upper Freeport coal overburden at Site L (Project 14010EJE).

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
5-6'	1	0	10 YR 7.5/4	.022	0.69	-2.72	3.41	
	2	0	10 YR 7/4	.009	0.28	-0.74	1.02	
	3	0	10 YR 7/4	.016	0.50	-0.50	1.00	
	4	0	10 YR 7/4	.012	0.37	-0.99	1.36	
	5	0	10 YR 7/6	.015	0.47	-0.99	1.46	
	6	0	10 YR 7.5/5	.017	0.53	-0.50	1.03	
	7	0	10 YR 7.5/4	.008	0.25	-0.25	0.50	
	8	No sample						
	9	0	10 YR 7.5/3	.006	0.19	0	0.19	
	10	0	10 YR 7.5/3	.005	0.16	-0.25	0.41	
	11	0	10 YR 7.5/3	.045	1.41	0.25	1.16	
	12	0	10 YR 8/1	.155	4.84	-0.50	5.34	
	13	0	10 YR 8/1	.160	5.00	0	5.00	
	14	0	10 YR 8/3	.185	5.78	-0.25	6.03	
	15	0	10 YR 8/2	.285	8.91	1.48	7.43	
	16	0	10 YR 8/3	.215	6.72	1.48	5.24	
	17	0	10 YR 8/1	.250	7.81	7.42	0.39	
	18	0	10 YR 7.5/2	.250	7.81	0.25	7.56	
	19	0	10 YR 7.5/1	.250	7.81	6.68	1.13	
	20	0	2.5 Y 8/1.5	.245	7.66	11.63		3.97
	21	0	10 YR 7.5/3	.220	6.88	6.19	0.69	
	22	1	10 YR 8/2	.260	8.12	34.40		26.28
	23	1	2.5 Y 8/3	.220	6.88	31.68		24.80
	24	1	2.5 Y 8/2	.220	6.88	6.93		0.05
	25	1	N 8/0	.225	7.03	6.93	0.10	

Table 19 (continued)

	26	0	2.5 Y 8/1	.165	5.16	0	5.16	
	27	0	N 8/0	.185	5.78	3.71	2.07	
	28	0	N 8/0	.195	6.09	0.50	5.59	
	29	0	N 8/0	.195	6.09	0.99	5.10	
	30	0	N 8/0	.190	5.94	4.21	1.73	
	31	0	N 8/0	.190	5.94	2.97	2.97	
	32	1	2.5 Y 7.5/2	.170	5.31	22.28		16.97
	33	1	2.5 Y 7.5/0	.930	29.06	14.11	14.95	
	34	1	2.5 Y 7.5/0	.460	14.38	18.81		4.43
	35	1	N 8/0	.210	6.56	7.18		0.62
	36	0	N 8/0	.220	6.88	2.97	3.91	
	37	0	N 8/0	.245	7.66	12.38		4.72
	38	0	N 8/0	.265	8.28	0.50	7.78	
	39	0	N 7.5/0	.640	20.00	13.61	6.39	
	40	1	2.5 Y 7/0	1.16	36.25	25.99	10.26	
	41	1	2.5 Y 7.5/0	.950	29.69	14.11	15.58	
	42	0	2.5 Y 5.5/0	2.65	82.81	-1.73	84.54	
	43	0	2.5 Y 5.5/1	2.40	75.00	-1.24	76.24	
	44	0	2.5 Y 5/1	2.40	75.00	-1.98	76.98	
	45	0	2.5 Y 5.5/1	1.10	34.38	1.73	32.65	
	46	0	2.5 Y 5.5/1	.525	16.41	3.96	12.45	
	47	0	2.5 Y 5.5/1	.525	16.41	-6.93	23.34	
	47-47 1/2	0	10 YR 2/1	.540	16.88	2.97	13.91	
-55'	48	0	2.5 Y 2.5/1	1.29	40.31	3.71	36.60	

Table 20

Sample characterization and Acid-Base Account of Upper Freeport coal overburden at Site A
(Project 14010EJE)

Depth	(Sample #)	Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material: Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
3-4'	1 SS	-	-	-	-	-	-	-
4-5'	2	-	-	.002	.06	-	-	-
	3	0	2.5 Y 8/1	.002	.06	0.99		.93
	4	0	10 YR 8/3	.008	.25	0	.25	
	5	0	10 YR 7.5/4	.005	.16	0	.16	
	6	0	10 YR 7.5/3	.004	.12	0	.12	
	7	0	2.5 Y 8/3	.005	.16	0.25		.09
	8	0	10 YR 7/4	.004	.12	0.25		.13
	9	-	-	.002	.06	-	-	-
	10	0	2.5 & 7.5/3	.003	.09	0.50		.41
	11	-	-	.003	.06	-	-	-
	12	0	10 YR 7/3	.006	.19	0.25		.06
	13	0	2.5 Y 8/3	.017	.53	0.25	.58	
	14	0	10 YR 8/2.5	.011	.34	0.25	.09	
	15	0	2.5 Y 8/3	.008	.25	-0.25		
	16	0	2.5 Y 8/2	.008	.25	-0.25		
	17	0	10 YR 8/2	.055	1.72	0	1.72	
	18	0	10 YR 8/2	.140	4.38	0.50	3.88	
	19	0	2.5 Y 8/1	.190	5.94	0.99	4.95	
	20	0	2.5 Y 8/3	.090	2.81	0.74	2.07	
	21	0	10 YR 7/4	.150	4.69	19.55		14.86
	22	-	-	.150	4.69	-	-	-
	23	1	2.5 Y 8/1	.128	4.00	9.40		5.40
	24	1	2.5 Y 7.5/2	.132	4.12	6.68		2.56

Table 20 (continued)

	25	1	2.5 Y 8/0	.140	4.38	26.48		22.10
	26	-	-	.127	3.97	-		
	27	1	2.5 Y 7.5/1	.138	4.31	2.48	1.83	
	28	1	2.5 Y 8/1	.160	5.00	18.32		13.32
	29	1	2.5 Y 7.5/1	.435	13.59	21.78		8.19
	30	1	2.5 Y 7.5/0	.435	13.59	26.48		12.89
	31	1	2.5 Y 7.5/0	.320	10.00	17.82		7.82
	32	1	2.5 Y 8/0	.496	15.50	15.34	.16	
	33	1	2.5 Y 8/0	.425	13.28	18.32		5.04
	34	-	-	.275	8.59	-		
	35	0	2.5 Y 7.5/0	.587	18.34	8.91	9.43	
	36	0	2.5 Y 8/0	.340	10.62	6.44	4.18	
39-40'	37	-	-	.386	12.06	-		
40-41'	38	-	-	.600	18.75	-		
41-42'	-							
42-43'	-							
43-	Upper Freeport Coal Seam							

southwest toward Glenville in Geologic Cross-Section A-A' (Figure 6) and discussed previously may also be applied to the lower Conemaugh in northern Preston County. This area could be considered a peripheral area of the main Upper Freeport coal swamp, which is to the north in western Pennsylvania, as evidenced by the predominating influence of sandstones in the overburden section, erratic, local thinning and thickening of the coal seam, and its eventual disappearance to the south (see also Geologic Cross-Section B-B', Figure 9). Sites B-B', 16 (Table 21) and B-B', 18 (Table 22), representing exploration cores through Kittanning overburdens in the northern part of Province 2, show the somewhat lower sulfur contents associated with the Allegheny Formation in this area. Detailed analyses prior to surface mining at Site O, northern extremity of Geologic Cross-Section B-B' (Figure 9) showed only a small danger of potential acid toxicity and also only a small neutralizing potential of rock strata below the weathered zone (Table 23). This site involved a natural soil that was inherently difficult to manage. The reclamation and revegetation subsequent to mining at Site O were successful. Sites B-B', 1a, b, and c represent Lower Kittanning overburden at the Southern end of Cross-section B-B' (Figure 9) just discussed. Figure 9 shows the increased complexity in coal seam/rock type relationships as one goes south along B-B'. The diverse nature of the rock types and compositions as seen in Tables 24, 25, and 26 supported by field observations of greatly varying coal seam intervals and thickness, lenses of channel sandstones locally prevailing or diminishing, and the general uncertain nature of coal and overburden quality present the surface mine operator and reclamationist with a challenging job. The mudrock underlying the predominantly sandstone overburden presents the best material for topsoiling a spoil area. There does not appear to be a significantly deep weathered zone of pyrite-free material in the sandstone caprock of this area. Indeed, it appears that where a thin coal seam (Middle Kittanning) persists only a few feet below the original land surface, weathering failed to penetrate appreciably into the underlying material.

SURFACE MINING PROVINCE 1

The rocks in this Province, the oldest found in the coal measures of West Virginia, provide low sulphur, metallurgical grade coal. Synonymously, a major portion of the coal overburden materials are quite low in pyritic sulfur content, with a corresponding low acid producing potential, although the rocks are not calcareous. Highly successful revegetation effects where sufficient plant nutrients have been applied on this minesoil material, along with little or no record of acid water discharges, verify the favorable nature of this material for plant growth. Tables 27, 28, and 29 provide data from analyses of rock chips from two sites sampled in northern Greenbrier

Table 21

Sample characterization and Acid-Base Account of Upper Freeport and Lower Kittanning coal overburden at Site B-B', 16.

Depth		Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material: Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
18.0-23.6'	SS	0	10 YR 7/4	.005	0.16	1.53		1.37
23.6-30.0'	SS	0	10 YR 7/4	.007	0.22	1.78		1.56
30.0-35.0'	SS	0	2.5 Y 7.5/0	.020	0.62	1.02		0.40
35.0-37.3'	SS	1	2.5 Y 8/0	.055	1.72	35.09		33.37
37.3-39.0'	SS	0	10 YR 7.5/2	.002	0.06	0	0.06	
39.0-40.0'	SS	0	10 YR 5.5/7	.003	0.09	3.04		2.95
40.0-40.7'	SS		10 YR 7.5/3	.002	0.06	1.02		0.96
40.7-40.9'	SS	0	2.5 Y 7/1	.055	1.72	3.29		1.57
40.9-42.3'	SS	0	10 YR 6.5/4	.004	0.12	2.78		2.66
42.3-45.0'	SS	1	2.5 Y 8/0	.300	9.38	35.09		25.71
45.0-46.0'	SS	0	10 YR 7/4	.002	0.06	1.28		1.22
57.1-62.2'	Upper Freeport coal seam							
75.0-80.0'	SS	3	2.5 Y 7.5/0	.027	0.84	100.15		99.31
80.0-82.9'	SS	1	2.5 Y 7.5/0	.065	2.03	24.48		22.45
82.9-85.0'	SS	0	2.5 Y 7.5/0	.014	0.44	5.05		4.61
85.0-90.0'	SS	0	2.5 Y 7.5/0	.045	1.41	5.56		4.15
90.0-91.0'	SS	0	2.5 Y 7.5/0	.020	0.62	14.15		13.53
91.0-96.0'	I	1	2.5 Y 7.5/0	.011	0.34	61.10		60.76
96.0-97.5'	SH	0	2.5 Y 7.5/0	.005	0.16	3.54		3.38
97.5-98.0'	SH	0	2.5 Y 7.5/0	.010	0.31	3.54		3.23
98.0-99.0	SH	0	2.5 Y 7.0/0	.011	0.34	6.07		5.73

Table 21 (continued)

99.0-100.0'	SH	0	2.5 Y 3/0	.041	1.28	7.06		5.78
100.0-101.0'	MR	0	10 YR 5.5/1	.040	1.25	7.06		5.81
101.0-101.6'	C	0	2.5 Y 2.5/0	2.95	92.19	4.03	88.16	
101.6-104.5'	MR	0	2.5 Y 2.5/0	.017	0.53	3.29		2.76
104.5-106.0'	MR	0	2.5 Y 7/1	.556	17.34	2.78	14.56	
106.0-107.0'	MR	0	2.5 Y 8/0	.008	0.25	10.86		10.61
107.0-108.0'	MR	0	2.5 Y 8/0	.012	0.38	2.02		1.64
108.0-109.5'	MR	1	2.5 Y 8/0	.011	0.34	16.17		15.83
109.5-111.5'	SH	4	2.5 Y 7.5/0	.024	0.75	145.87		145.12
111.5-113.0'	SS	0	2.5 Y 7.5/0	.010	0.31	5.05		4.74
113.0-115.0'	SS	0	2.5 Y 7.5/0	.024	0.75	5.05		4.30
115.0-117.0'	SS	0	2.5 Y 7/0	.006	0.19	11.63		11.44
117.0-120.0'	SS	0	2.5 Y 7/0	.085	2.66	3.80		1.14
120.0-122.0'	SS	0	2.5 Y 7/0	.060	1.88	4.06		2.18
122.0-125.0'	SS	0	2.5 Y 7.5/0	.075	2.34	2.02	0.32	
125.0-130.0'	SS	1	2.5 Y 7.5/0	.075	2.34	13.39		11.05
130.0-135.0'	SS	1	2.5 Y 8/0	.035	1.09	12.88		11.79
135.0-140.0'	SS	4	2.5 Y 7.5/0	.019	0.59	234.96		234.37
140.0-145.0'	SS	1	2.5 Y 7.5/0	.022	0.69	12.39		11.70
145.0-149.5'	SS	0	2.5 Y 7.5/0	.026	0.81	3.04		2.23
149.5-150.0'	SS	0	2.5 Y 7.5/0	.060	1.88	8.85		6.97

Table 22

Sample characterization and Acid-Base Account of Lower Kittanning coal overburden at Site B-B', 18.

						Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)		Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
272.0-275.5'	Lower Freeport coal seam								
277.5-278.5'	1	MR	0	2.5 Y 7.5/1	.022	.69	3.21		2.52
278.5-280.0'	2	MR	0	2.5 Y 7/1	.365	11.41	-1.48	12.89	
280.0-281.0'	3	SH	0	2.5 Y 7/1	.070	2.19	15.59		13.40
281.0-282.0'	4	MR	0	2.5 Y 7.5/1	.017	.53	3.96		3.43
282.0-	5	MR	0	2.5 Y 7.5/1	.009	.28	3.71		3.43
	6	MR	0	2.5 Y 7.5/1	.008	.25	2.97		2.72
	7	MR	0	2.5 Y 7.5/1	.006	.19	3.71		3.52
-296.0'	8	MR	0	2.5 Y 7/1	.009	.28	3.46		3.18
296.0-298.5'	9	SH	0	2.5 Y 6.5/1	.010	.31	3.96		3.65
298.5-299.0'	10	SS	0	2.5 Y 8/0	.016	.50	12.38		11.88
299.0-302.5'	11	I	-	-	-	-	-		-
302.5-303.5'	12	SS	1	2.5 Y 7.5/0	.095	2.97	14.85		11.88
319.5-321.5'	13	SS	1	2.5 Y 7/1	.125	3.91	28.22		24.31
322.0-323.0'	14	MR	4	2.5 Y 5/1	4.00	125.0	249.86		124.86
323.0-326.0'	15	SS	0	2.5 Y 5.5/1	.725	22.66	17.08	5.58	
326.0-326.5'	16	MR	0	2.5 Y 6.5/1	1.125	35.16	7.42	27.74	
326.5-	17	SH	3	2.5 Y 7/1	.025	.78	127.39		126.61
-333.5'	18	SH	0	2.5 Y 7/0	.012	.38	11.38		11.00
334.0-336.0'	19	SH	0	2.5 Y 6.5/1	.010	.31	7.42		7.11
336.0-339.5'	20	SH	0	2.5 Y 6.5/1	.040	1.25	7.67		6.42
339.5-	21	SH	0	2.5 Y 7/1	.017	.53	7.42		6.89
	22	SH	0	2.5 Y 6.5/1	.006	.19	7.18		6.99
	23	SH	1	2.5 Y 7/1	.035	1.09	28.22		27.13
	24	I	0	2.5 Y 7.5/0	.007	.22	5.20		4.98

Table 22 (continued)

	25	I	1	2.5 Y 7/0	.050	1.56	12.87		11.31
	26	I	0	2.5 Y 7/1	.065	2.03	5.69		3.66
-354.0'	27	SH	0	2.5 Y 7/1	.008	.25	7.42		7.17
354.0-356.0'	28	SH	0	2.5 Y 5.5/1	.030	.94	23.76		22.82
356.0-	29	SH	0	2.5 Y 5/1	1.035	32.34	12.13	20.21	
-360.0'	30	SH	0	2.5 Y 6.5/1	.010	.31	9.90		9.59
-360.5'	Upper Kittanning coal seam position (3")								
366.0-	31	SH	0	2.5 Y 6/1	.025	.78	20.79		20.01
-372.0'	32	SH	0	2.5 Y 6/1	.023	.72	17.08		16.36
-373.0'	Middle Kittanning coal seam (1')								
376.0-	33	I	0	2.5 Y 5/1	.070	2.19	13.61		11.42
-379.0'	34	I	0	2.5 Y 6.5/1	.040	1.25	14.36		13.11
379.0-380.0'	35	SS	1	2.5 Y 7/0	.050	1.56	26.98		25.42
380.0-	36	I	0	2.5 Y 5/1	.170	5.31	14.60		9.29
-385.0'	37	I	0	2.5 Y 5.5/1	.065	2.03	12.13		10.10
385.0-386.5'	38	I	0	2.5 Y 5.5/1	.080	2.50	14.36		11.86
386.5-	39	I	0	2.5 Y 5.5/1	.040	1.25	10.89		9.64
-390.5'	40	I	0	2.5 Y 6/1	.040	1.25	11.38		10.13
390.5-	41	I	0	2.5 Y 6/1	.045	1.41	6.19		4.78
	42	I	0	2.5 Y 5.5/1	.215	6.72	13.61		6.89
-399.5'	43	I	0	2.5 Y 5.5/1	.125	3.91	8.42		4.51
400.0-	44	MR	0	2.5 \ 6/1	.023	.72	8.66		7.94
	45	MR	0	2.5 Y 6/1	.025	.78	8.66		7.88
-406.0'	46	MR	0	2.5 Y 5.5/1	.030	.94	10.40		9.46

Table 23

Sample characterization and Acid-Base Account of Lower Kittanning coal overburden at Site O (Project 14010EJE).

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
0-7"		all are zero	2.5 Y 6/2	.036	1.12	-2.85	3.97	
0.5-2'			10 YR 7/3	.022	.68	-7.76	8.44	
2-4'	34.36		10 YR 7/4	.014	.44	-5.12	5.56	
4-8'	30-34		10 YR 8/2	.010	.31	-6.32	6.63	
6-8'	30-32		10 YR 7/3	.004	.12	-4.53	4.65	
8-10'	28-30		7.5 YR 8/4	.007	.22	-3.42	3.64	
10-12'	26-28		10 YR 8/4	.008	.25	-3.62	3.87	
12-14'	24-26		10 YR 8/4	.005	.15	-3.26	3.41	
14-16'	22-24		10 YR 8/3	.005	.15	-3.26	3.41	
16-18'	20-22		10 YR 8/4	.006	.18	-2.28	2.46	
18-20'	18-20		2.5 Y 8/4	.006	.18	-2.28	2.46	
20-22'	16-18		10 YR 7/3	.011	.34	-3.58	3.92	
22-24'	14-16		10 YR 7/4	.013	.40	-1.88	2.28	
24-26'	12-14		10 YR 7/4	.010	.31	-2.91	3.22	
26-28'	10-12		7.5 YR 7/6	.016	.50	-2.72	3.22	
28-30'	8-10		10 YR 7/4	.015	.46	-3.80	4.26	
30-32'	6-8		10 YR 7/4	.010	.31	-6.18	6.49	
32-34'	4-6		10 YR 7/4	.008	.25	-1.98	2.23	
34-36'	2-4		10 YR 7/4	.004	.12	-2.27	2.39	
36-37'	1-2		10 YR 7/3	.011	.34	-3.42	3.76	
36-38'	0-2		10 YR 7/5	.007	.22	-1.40	1.62	
38-39'	1		2.5 Y 6/2	.036	1.12	-1.12	2.24	
39-40'	2		2.5 Y 7/2	.015	.46	-1.38	1.84	
40-41'	3		2.5 Y 7/2	.025	.78	.22	0.56	
							8.25	

Table 23 (continued)

41-42'	4	2.5 Y 6/0	.090	2.81	-5.44	8.25	
42-43'	5	2.5 Y 5/0	.105	3.28	6.62		3.34
43-44'	6	2.5 Y 6/0	.060	1.88	7.18		5.30
44-45'	7	2.5 Y 6/0	.085	2.66	8.10		5.44
45-46'	8	2.5 Y 6/0	.070	2.18	4.88		2.70
46-47'	9	2.5 Y 6/2	.045	1.40	8.97		7.57
47-48'	10	2.5 Y 6/0	.075	2.34	3.93		1.59
48-49'	11	2.5 Y 6/0	.090	2.81	5.35		2.54
49-50'	12	10 YR 6/1	.065	2.03	4.76		2.73
50-51'	13	10 YR 6/1	.040	1.25	5.48		4.23
51-52'	14	10 YR 6/1	.045	1.40	5.58		4.18
52-53'	15	10 YR 6/1	.075	2.34	6.29		3.95
53-54'	16	10 YR 6/1	.120	3.75	6.42		2.67
54-55'	17	10 YR 6/1	.125	3.90	5.76		1.86
55-56'	18	10 YR 6/1	.065	2.03	6.36		4.33
56-57'	19	10 YR 6/1	.095	2.96	6.63		3.67
57-58'	20	10 YR 6/1	.060	1.88	5.48		3.60
58-59'	21	10 YR 6/1	.055	1.72	7.26		5.54
59-60'	22	10 YR 6/1	.095	2.96	7.85		4.89
60-61'	23	10 YR 6/1	.060	1.88	8.93		7.05
61-62'	24	10 YR 6/1	.055	1.72	8.58		6.86
62-63'	25	10 YR 6/1	.080	2.50	7.80		5.30
63-64'	26	10 YR 6/1	.045	1.40	7.28		5.88
64-65'	27	-	.055	1.72	8.00		6.28
65-66'	28	-	.045	1.40	8.08		6.68
66-67'	29	10 YR 6/1	.065	2.03	7.82		5.79
67-68'	30	10 YR 6/1	.060	1.88	8.26		6.38
68-69'	31	10 YR 6/1	.055	1.72	10.12		8.40
69-70'	32	2.5 Y 6/0	.070	2.18	9.30		7.12
71-72'	33	2.5 Y 6/0	-	-	-	-	-
72-73'	34	-	.055	1.72	4.88		3.16
73-74'	35	-	.225	7.03	4.12	2.91	

Table 23 (continued)

74-75'	36	-	1.10	34.38	3.22	31.16
75-76'	37	-	.350	10.95	2.84	8.10
76-77'	38	-	.165	5.16	1.30	3.86
77-78'	39	-	.715	22.34	1.36	20.98
78-79'	40	-	2.43	75.94	1.16	74.78
79-80'	41	2.5 Y 2/0	1.52	47.50	1.18	46.32
80-	Lower Kittanning coal seam					

Table 24

Sample characterization and Acid-Base Account of Lower Kittanning coal overburden at Site B-B', la.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
0' - 1'								
1' - 2'								
2' - 3'								
3' - 4'	1 C	0	10 YR 3/1	0.145	4.53	-0.59	5.12	-
4' - 5'	2	0	10 YR 4/1	0.220	6.88	-0.46	7.34	-
	3	0	10 YR 4/1	0.355	11.09	-0.14	11.23	-
	4	0	10 YR 4/1	0.410	12.81	-0.46	13.27	-
	5	0	10 YR 3/1	0.580	18.13	-0.21	18.34	-
	6	0	10 YR 5/1	0.335	10.47	-0.21	10.68	-
	7	0	10 YR 2/1	0.595	18.59	-0.40	18.99	-
	8	0	10 YR 5/1	0.380	11.86	-0.40	12.26	-
	9	0	10 YR 4/1	0.700	21.86	-0.85	22.71	-
	10	0	10 YR 6/1	0.275	8.59	-0.21	8.80	-
	11	0	10 YR 7/1	0.135	4.22	-0.08	4.30	-
	12	0	N 7/	0.070	2.19	-0.40	2.59	-
	13	0	2.5 Y 8/0	0.035	1.09	-0.33	1.42	-
	14	0	2.5 Y 8/0	0.075	2.34	-0.21	2.55	-
	15	0	2.5 Y 8/0	0.065	2.03	-0.08	2.11	-
	16	0	2.5 Y 8/0	0.045	1.41	0.14	1.27	-
	17	0	N 7/	0.115	3.59	-0.06	3.65	-
	18	0	5 Y 6/1	0.225	7.03	-1.03	8.06	-
	19	0	2.5 Y 8/0	0.020	0.62	0.00	0.63	-
	20	0	2.5 Y 8/0	0.035	1.09	0.13	0.96	-
	21	0	N 7/	0.150	4.69	0.00	4.69	-

Table 24 (continued)

22	0	2.5 Y 7/0	0.200	6.25	0.00	6.25	-
23	0	2.5 Y 8/0	0.055	1.72	-0.13	1.85	-
24	0	2.5 Y 8/0	0.065	2.03	0.13	1.90	-
25	0	2.5 Y 8/0	0.100	3.13	-0.26	3.39	-
26	0	2.5 Y 7/0	0.310	9.69	-0.26	9.95	-
27	0	2.5 Y 7/0	0.300	9.38	-0.06	9.44	-
28	0	10 YR 5.0	1.140	35.63	0.00	35.63	-
29	0	10 YR 2/0	2.625	82.03	0.13	81.90	-
30 C	0	10 YR 2/1	5.500	171.88	-1.16	173.04	-
31	0	10 YR 6/1	2.750	85.94	-3.03	88.97	-
32	0	7.5 YR 7/0	2.200	68.75	-4.05	72.80	-
33	0	7.5 YR 7/0	1.475	46.09	-3.79	49.88	-
34	0	10 YR 7/1	1.275	39.84	-3.16	43.00	-
35	0	7.5 YR 7/0	0.640	20.00	-2.90	22.90	-
36	0	7.5 YR 7/0	0.455	14.22	-1.75	15.97	-
37	0	10 YR 7/1	0.205	6.41	2.17	4.24	-
38	0	10 YR 7/1	0.170	5.31	3.03	2.28	-
39	0	10 YR 7/1	0.215	6.72	2.49	4.23	-
40	0	10 YR 7/1	0.125	3.91	5.95	-	2.04
41	0	2.5 Y 7/2	0.125	3.91	6.27	-	2.36
42	0	2.5 Y 7/2	0.090	2.81	6.08	-	2.27
43	0	2.5 Y 7/2	0.080	2.50	6.14	-	3.64
44	0	5 Y 7/1	0.085	2.66	3.32	-	0.66
45	0	5 Y 7/1	0.090	2.81	3.77	-	0.96
46	0	5 Y 7/1	0.050	1.56	5.78	-	4.22
47	0	5 Y 7/1	0.050	1.46	5.33	-	3.77
48	0	5 Y 7/1	0.045	1.51	4.75	-	3.34
49	0	5 Y 7/1	0.025	0.78	4.88	-	4.10
50	0	5 Y 7/1	0.015	0.47	3.34	-	2.87
51	0	5 Y 7/1	0.025	0.78	3.14	-	2.36

Table 24 (continued)

	52	0	5 Y 7/1	0.020	0.63	2.70	-	2.07
	53	0	5 Y 7/1	0.020	0.63	3.60	-	2.97
	54	0	5 Y 7/1	0.025	0.78	2.83	-	2.05
	55	0	5 Y 7/1	0.020	0.63	2.83	-	2.20
	56	0	5 Y 7/1	0.030	0.94	0.77	0.17	-
	57	0	5 Y 7/1	0.030	0.94	0.26	0.68	-
	58	0	5 Y 7/1	0.015	0.47	0.51	-	0.04
	59	0	5 Y 7/1	0.025	0.78	0.13	0.65	-
	60	0	5 Y 7/1	0.030	0.94	0.77	0.17	-
	61	0	5 Y 7/1	0.015	0.47	1.16	-	0.69
	62	0	5 Y 7/1	0.010	0.31	1.54	-	1.23
	63	0	5 Y 7/1	0.020	0.63	1.54	-	0.91
	64	0	5 Y 7/1	0.010	0.31	2.83	-	2.52
	65	0	5 Y 7/1	0.035	1.09	2.57	-	1.48
	66	0	5 Y 7/1	0.070	2.19	0.39	1.80	-
	67	0	5 Y 5/1	0.325	10.16	-0.64	10.80	-
	68 SH	0	2.5 Y 4/0	1.425	44.53	0.51	44.02	-
	69 SH	0	2.5 Y 4/0	1.450	45.31	0.26	45.05	-
	70	0	2.5 Y 3/0	1.050	32.81	0.51	32.30	-
	71	0	10 YR 3/1	1.025	32.03	1.03	31.00	-
	72	0	2.5 Y 2/0	1.125	35.16	0.64	34.52	-
	73	0	2.5 Y 2/0	1.075	33.59	1.16	32.43	-
	74	0	2.5 Y 2/0	1.700	53.13	0.39	52.74	-
	75	0	2.5 Y 2/0	2.400	75.00	-0.13	75.13	-
	76 SH	0	2.5 Y 2/0	1.625	50.78	-0.26	51.04	-
	77	0	10 YR 6/1	1.925	60.16	-2.31	62.47	-
-78'	78	0	5 Y 7/1	0.355	11.09	-1.29	12.38	-

Table 25

Sample characterization and Acid-Base Account of Lower Kittanning coal overburden at Site B-B', 1b.

Depth	(Sample #)		Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
27-28'	1	MS	0	5 Y 6.5/1	.014	0.44	6.71		6.27
	2	MS	0	5 Y 7/2	.035	1.09	7.45		6.36
	3	MS	0	5 Y 7/2	.014	0.44	8.18		7.74
	4	MS	0	5 Y 6.5/1	.014	0.44	3.21		2.77
	5	MS	0	5 Y 7/1	.010	0.31	3.47		3.16
	6	MS	0	5 Y 7/2	.006	0.19	7.96		7.77
	7	MS	0	5 Y 6.5/1	.004	0.12	4.21		4.09
	8	MS	0	5 Y 6.5/1	.035	1.09	4.95		3.86
	9	MS	0	5 Y 6.5/1	.125	3.91	7.19		3.28
	10	MS	0	5 Y 6.5/1	.030	0.94	1.73		0.79
	11	MS	0	5 Y 6.5/1	.012	0.38	1.22		0.84
	12	MS	0	5 Y 6.5/1	.008	0.25	-0.26	0.51	
	13	MS	0	5 Y 6.5/1	.012	0.38	-0.51	0.89	
-43'	14	MS	0	5 Y 5.5/1	.085	2.66	-1.28	3.94	
	15		Lower Kittanning coal seam						

Table 26

Sample characterization and Acid-Base Account of Lower Kittanning coal overburden at Site B-B', lc.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
0-1'	1	0	10 YR 7/2	.008	0.25	-0.74	0.99	
	2	0	10 YR 7/2	.004	0.12	-0.48	0.60	
	3	0	2.5 Y 7/1	.008	0.25	0.03	0.22	
	4	0	2.5 Y 6.5/2	.030	0.94	-0.48	1.42	
	5	0	2.5 Y 6/1	.060	1.88	3.77		1.89
	6	0	2.5 Y 6/1	.095	2.97	1.53	1.44	
	7	0	2.5 Y 6/1	.065	2.03	1.76	0.27	
	8	0	2.5 Y 6/1	.100	3.12	0.76	2.36	
	9	0	2.5 Y 6/1	.345	10.78	0.51	10.27	
	10	0	2.5 Y 6.5/1	.095	2.97	-0.74	3.71	
	11	0	2.5 Y 7/1	.040	1.25	-0.48	1.73	
	12	0	2.5 Y 7/1	.040	1.25	0.28	0.97	
	13	0	2.5 Y 7/1	.004	0.12	-0.23	0.35	
	14	0	2.5 Y 6.5/1	.008	0.25	0.28		0.03
	15	0	2.5 Y 6.5/1	.019	0.59	-0.23	0.82	
	16	0	10 YR 4.5/1	.330	10.31	0.03	10.28	
	17	0	10 YR 5.5/1	.380	11.88	0.03	11.85	
	18	0	2.5 Y 6.5/1	.190	5.94	-0.23	6.17	
	19	0	2.5 Y 6/1	.095	2.97	0.51	2.46	
	20	0	2.5 Y 5/1	.600	18.75	0.03	18.72	
	21	0	2.5 Y 6.5/0	.270	8.44	0.28	8.16	
	22	0	2.5 Y 6.5/0	.325	10.16	0.28	9.88	
	23	0	2.5 Y 6.5/0	.370	11.56	0.03	11.53	
	24	0	2.5 Y 6/0	.850	26.56	0.50	26.05	
	25	0	2.5 Y 6/0	.540	16.88	0.51	16.37	

Table 26 (continued)

	26	0	2.5 Y 6/0	.225	7.03	0.51	6.52
	27	0	2.5 Y 6.5/0	.280	8.75	0.28	8.47
	28	0	2.5 Y 6.5/0	.230	7.19	0.03	7.16
	29	0	2.5 Y 7/0	.425	13.28	0.76	12.52
	30	0	2.5 Y 7/0	.245	7.66	1.02	6.64
	31	0	2.5 Y 7/1	.230	7.19	0.76	6.43
	32	0	2.5 Y 7/0	.675	21.09	0.28	20.81
	33	0	2.5 Y 6/1	.024	0.75	0.03	0.72
	34	0	2.5 Y 7/1	.105	3.28	0.51	2.77
	35	0	2.5 Y 5.5/0	.715	22.34	-0.23	22.57
-42'	36	0	2.5 Y 4/1	1.07	33.44	2.27	31.17
46-	Lower Kittanning coal seam						

Table 27

Sample characterization and Acid-Base Account of Sewell coal overburden at Site MM.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
2-3'	3	0	10 YR 7.5/3	.002	.06	-0.23	.29	-
3-4'	4	0	5 Y 7.5/3	.002	.06	-0.23	.29	-
4-5'	5	0	5 Y 7.5/2.5	.002	.06	-0.23	.29	-
5-6'	6	0	5 Y 7.5/2.5	.001	.03	-0.23	.26	-
6-7'	7	0	5 Y 7.5/2.5	.001	.03	0.03	.29	-
7-8'	8	0	2.5 Y 7.5/3	.002	.06	-0.49	.55	-
8-9'	9	0	2.5 Y 7.5/3	.002	.06	-0.75	.81	-
9-10'	10	0	10 YR 7/3	.002	.06	-0.75	.81	-
10-11'	11	0	10 YR 7/3.5	.001	.03	-0.75	.78	-
11-12'	12	0	10 YR 7.5/2	.001	.03	0.03	0	-
12-13'	13	0	2.5 Y 8/0	.003	.09	0.03	.06	-
13-14'	14	0	10 YR 7.5/3	.001	.03	-0.75	.78	-
14-15'	15	0	2.5 Y 7/3	.003	.09	-0.49	.58	-
15-16'	16	0	10 YR 5.5/2	.022	.69	-1.24	1.93	-
16-17'	17	0	2.5 Y 7/2	.022	.06	0.03	.03	-
17-18'	18	0	2.5 Y 7.5/2	.001	.03	-0.23	.26	-
18-19'	19	0	2.5 Y 6.5/2	.008	.25	-0.49	.74	-
19-20'	20	0	2.5 Y 6.5/2	.003	.09	-0.49	.58	-
20-21'	21	0	2.5 Y 6.5/2	.002	.06	-0.23	.29	-
21-22'	22	0	10 YR 6.5/3	.005	.16	0.03	.13	-
22-23'	23	0	10 YR 7.5/2	.002	.06	-0.49	.55	-
23-24'	24	0	2.5 Y 7.5/2	.003	.09	0.03	.06	-
24-25'	25	0	2.5 Y 7.5/3	.001	.03	-0.23	.26	-
25-26'	26	0	10 YR 6.5/5	.002	.06	0.03	.03	-

Table 28

Sample characterization and Acid-Base Account of Sewell coal overburden at Site NN-a.

Depth	(Sample #)	Fiz	Color	%S	Tons per Thousand Tons of Material Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
14" INTERVALS	1	-	5 Y 5.5/1	.016	.50	12.38		11.88
	2	-	5 Y 5.5/1	.019	.59	10.12		9.53
	3	-	5 Y 5.5/1	.021	.66	12.90		12.24
	4	-	10 YR 5.5/1	.025	.78	12.64		11.86
	5	-	10 YR 5.5/1	.039	1.22	11.12		9.90
	6	-	10 YR 6/1	.030	.94	11.38		10.44
	7	-	10 YR 6/1	.028	.88	11.38		10.50
	8	-	10 YR 5.5/1	.022	.69	7.34		6.65
	9	-	10 YR 4/1	.110	3.44	13.65		10.21
	10	-	10 YR 4/1	.080	2.50	12.13		9.63
	11	-	5 Y 4/1	.050	1.56	12.38		10.82
	12	-	5 Y 4/1	.050	1.56	13.78		12.22
	13	-	5 Y 5.5/1	.050	1.56	11.59		10.03
	14	-	5 Y 6/1	.031	.97	7.34		6.37
	15	-	5 Y 6/1	.038	1.19	10.67		9.48
	16	-	10 YR 6.5/1	.030	.94	9.12		8.18
	17	-	10 YR 6.5/1	.019	.59	11.64		11.05
	18	-	10 YR 6.5/1	.026	.81	9.35		8.54
	19	-	10 YR 6.5/1	.030	.94	17.69		16.75
	20	-	5 Y 6.5/1	.021	.66	19.21		18.55
Top of coal	21	-	10 YR 3.5/1	.255	7.97	6.08	1.89	

Table 29

Sample characterization and Acid-Base Account of Sewell coal overburden at Site NN-b.

					Tons per Thousand Tons of Material			
Depth	(Sample #)	Fiz	Color	%S	Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
5-6'	1	-	10 YR 7/1.5	.003	0.09	-0.97	1.06	
6-7'	2	-	10 YR 7/2.5	.002	0.06	-1.24	1.30	
	3	-	10 YR 6.5/3	.004	0.12	-0.97	1.09	
	4	-	2.5 Y 7/3	.004	0.12	-1.48	1.60	
	5	-	5 Y 7/2.5	.004	0.12	-0.43	0.55	
	6	-	5 Y 7/2.5	.006	0.19	1.19		1.00
	7	-	10 YR 7/2.5	.006	0.19	-0.70	0.89	
	8	-	5 Y 7/3	.004	0.12	0.38		0.26
	9	-	2.5 Y 6.5/3	.005	0.06	0.11	0.06	
	10	-	10 YR 6/3	.004	0.12	0.92		0.80
	11	-	2.5 Y 6/2	.009	0.28	1.19		0.91
	12	-	2.5 Y 6/2	.012	0.38	5.51		5.13
	13	-	2.5 Y 6/2	.007	0.22	0.65		0.43
	14	-	2.5 Y 6/1.5	.011	0.34	2.27		1.93
	15	-	5 Y 6/1	.012	0.38	2.81		2.43
	16	-	5 Y 5.5/1	.017	0.53	3.35		2.82
	17	-	5 Y 5.5/1	.011	0.34	3.62		3.28
	18	-	5 Y 6/1	.008	0.25	4.16		3.91
	19	-	5 Y 6/1.5	.006	0.19	2.02		1.83
	20	-	2.5 Y 6/2	.006	0.19	0.96		0.77
	21	-	2.5 Y 5/2	.006	0.19	1.89		1.70
	22	-	2.5 Y 5/2	.007	0.22	2.70		2.48
	23	-	5 Y 5.5/1	.008	0.25	2.70		2.45
	24	-	5 Y 5/1	.020	0.62	3.24		2.62
	25	-	5 Y 5/1	.020	0.62	6.99		6.37

Table 29 (continued)

26	-	2.5 Y 6/1	.020	0.62	13.45	12.83
27	-	5 Y 5.5/1	.010	0.31	4.02	3.71
28	-	5 Y 5/1	.016	0.50	6.72	6.22
29	-	5 Y 5.5/1	.010	0.31	4.56	4.25
30	No Sample					
31	-	5 Y 5/1	.017	0.53	9.13	8.60
32	-	5 Y 5/1	.017	0.53	6.18	5.65
33	-	5 Y 5/1	.009	0.28	4.83	4.55
34	-	2.5 Y 5/2	.008	0.25	3.48	3.23
35	-	2.5 Y 5/2	.004	0.12	5.10	4.98
36	-	2.5 Y 5/2	.005	0.16	4.56	4.40
37	-	2.5 Y 5/1	.014	0.44	4.97	4.53
38	-	2.5 Y 5/1	.012	0.38	6.45	6.07
39	-	5 Y 5.5/1	.018	0.56	10.75	10.19
40	-	5 Y 5/1	.020	0.62	9.67	9.05
41	-	5 Y 5/1	.021	0.66	7.53	6.87
42	-	5 Y 5.5/1	.020	0.62	12.23	11.61
43	-	5 Y 5.5/1	.030	0.94	9.13	8.19
44	-	5 Y 5.5/1	.022	0.69	18.28	17.59
45	-	5 Y 5/1	.029	0.91	16.79	15.88
46	No Sample					
47	-	5 Y 5/1	.055	1.72	16.55	14.83
48	-	5 Y 5.5/1	.030	0.94	8.18	7.24
49	-	5 Y 5.5/1	.042	1.31	13.58	12.27
50	-	5 Y 5.5/1	.030	0.94	12.77	11.83
51	-	5 Y 4/1	.150	4.69	22.57	17.88
52	-	5 Y 5/1	.125	3.91	20.68	16.77
53	-	5 Y 5/1	.020	2.81	22.03	19.22
54	-	5 Y 4/1	.070	2.19	18.55	16.36
55	-	5 Y 4/1	.065	2.03	18.28	16.25
56	-	5 Y 5.5/1	.055	1.72	7.53	5.81
57	-	5 Y 5.5/1	.039	1.22	10.21	8.99
58	-	5 Y 6/1	.036	1.12	12.37	11.25

Table 29 (continued)

	59	-	5 Y 6/1	.029	0.91	9.94		9.03
	60	-	5 Y 6/1	.027	0.84	9.13		8.29
	61	-	5 Y 6/1	.028	0.88	9.26		8.38
	62	-	5 Y 6/1	.029	0.91	8.45		7.54
	63	-	5 Y 6/1	.032	1.00	12.50		11.50
	64	-	5 Y 6/1	.028	0.88	8.99		8.11
59-60'	65	-	5 Y 4/1	.130	4.06	6.59		2.53
Top of coal	66A	-	5 Y 3/1	.300	9.38	3.89	5.49	
	66B	-	5 Y 3/1	.310	9.69	3.75	5.94	

County. Site MM is predominantly sandstone caprock overlying the Sewell coal seam at elevations of about 4000 feet; and Sites NNa and b are shale overlying the same coal seam a little distance away. Boring NNb was about 100 feet upslope from NNa and provides a much deeper section of overburden for evaluation. The thin, higher-sulfur stratum appearing as NNa, 9 and NNb, 51-52 assure a reasonable lateral correlation of the two boreholes. Inasmuch as primary emphasis in this project has been oriented toward areas with more significant revegetation problems, extensive sampling and overburden analyses have not been pursued in Surface Mining Province 1. Even so, most of the trends and principles developed through intensive studies of other areas appear to apply to this region also.

IMPLICATIONS OF EVALUATION OF ACID-BASE ACCOUNT OF OVERBURDEN MATERIAL

In order to utilize the research information acquired during overburden and minesoil investigations, we have applied results of certain measurements to some practical situations. In cases where it is necessary to identify toxic or potentially toxic materials in overburden of coal or other resource prior to surface mining, we have accepted that a satisfactory definition can be provided by three measurements and their interpretation. These measurements, by methods previously described in detail, are: (1) pH of the pulverized rock slurry in distilled water; (2) total or pyritic sulphur; (3) "neutralization potential" or calcium carbonate equivalent.

With the results of these tests at hand, toxic or potentially toxic material is defined as any rock or earth material having a pH of less than 4.0 or a net potential deficiency of 5.0 tons of calcium carbonate equivalent or more per 1000 tons of material, by the acid-base accounting method. The accounting includes maximum potential acidity possible from immediately titratable sources plus sulphur expressed as sulphuric acid equivalent, and balances acidity against total neutralization potential from alkaline carbonates, exchangeable bases, weatherable silicates or other rock sources capable of neutralizing strong acids as measured by the neutralization potential.

This definition will credit more acid potential to the sulphur than is justified when part of the sulphur occurs in sulphate or organic forms. However, with most rocks studied to date, except carbon-rich rocks ("Carboliths") the error is insignificant. Moreover, as stated, determination of pyritic sulphur may be substituted for total sulphur if desired, but the determination is more complex and only in rare cases will the classification of the rock as toxic or non-toxic be changed by determining pyritic sulphur only.

The choice of the deficiency of 5 tons of calcium carbonate equivalent per 1000 tons of material as the division between toxic and non-toxic material, obviously is arbitrary. However, when applied to the large number of samples studied, it corresponds rather satisfactorily to other supporting laboratory information about these samples as well as to extensive field experiences with minesoils developing in the different rock types. If rock or soil samples were defined to be toxic at much lower calcium carbonate equivalent deficiencies than 5 tons per 1000 tons, we would be declaring many of our natural soils to be toxic. On the other hand, with deficiencies much greater than 5 tons per 1000 tons, pH values below 4.0 and toxic concentrations of plant-available aluminum often develop rapidly and are difficult to prevent with near surface applications of reasonable amounts of pulverized limestone.

In considering these standards, as defined, it may be convenient to recall that, chemically, one ton of calcium carbonate equivalent corresponds with 2 milliequivalents per 100 grams of material, and that 1000 tons is the theoretical weight of an acre plot-layer, as the term is used by many agriculturalists.

In summary, we suggest that toxic or potentially toxic rock or soil, as represented in surface mining of coal in the Appalachian coal basins, may be defined by three relatively simple laboratory measurements: (1) pH; (2) total or pyritic sulphur; and (3) neutralization potential. Also, the methods of applying these measurements to coal overburden materials have been described in detailed step-by-step procedures. A suggested form for plotting these measurements in relation to depth in a section of overburden is provided as Appendix G.

SECTION VIII

CHEMISTRY AND MINERALOGY OF PROFILES

Average rock composition is not expected to apply to all situations, but it may be helpful to keep in mind that sedimentary rocks, in general, are known to contain higher neutralizing potentials than the maximum acid potentials from pyritic sulfur (Clarke, and Washington, 1924). In fact, calcium alone in 253 composite sandstone samples analyzed averaged 98 times the molar equivalence necessary to neutralize all possible sulfuric acid that could form from the total sulfur content measured. Moreover, with 78 shales, calcium averaged 6.8 times the amount required for neutrality; and with 345 limestones the calcium averaged 1518 times the acid equivalence from sulphur.

Soiltest results for several overburden profiles are summarized in Tables 30 through 47. Such data are useful when used with discretion and especially when synthesized with acid-base accounts, indices of physical weathering potentials, and rock types.

In some cases, such as Site AA (Table 30), the depth of weathering is indicated clearly by the pH change from 3.8 for sample 23 to 7.5 for sample 25 (two feet deeper than sample 23) and corresponding changes of lime requirement from 6.75 to zero tons, and in both calcium and magnesium from relatively low to very high levels.

A similar weathering break in pH and lime requirement occurs between samples 10 and 12 at Site FF (Table 31). Distinctive changes in calcium, magnesium and phosphorus occur in approximately the same depth zone. Other examples of the same phenomenon include Sites HH, NN-b, PP (very shallow depth), and Site O. The full significance of the weathered zone was treated in some detail in early work concentrated on the overburden of the Upper Freeport coal in Preston County (West Virginia University, 1971a). In a case like Site PP the shallow depth of leaching reflects the fine texture and the great excess of calcium carbonate in the original, unweathered rock from which the soil has formed. So long as carbonates are present the pH is buffered near neutrality or above and many weathering processes are prevented or delayed.

Table 30

Soiltest results for Upper Freeport coal overburden at Site AA.

			Tons per Thousand Tons of Material	Pounds per Thousand Tons of Material			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
0-1'	1	4.6	8.25	80	300	1440	144
	2	4.2	5.25	47	146	240	42
	3	4.4	3.75	77	159	200	144
	4	--	--	--	--	--	--
	5	4.3	8.25	67	256	240	174
	6	4.3	6.75	72	275	128	150
	7	4.3	9.75	56	168	80	102
	8	4.8	2.25	58	268	3760	600+
	9	4.6	4.50	54	253	40	96
	10	4.6	3.75	45	206	80	114
	11	4.3	7.50	47	247	80	150
	12	5.0	1.50	50	256	4000+	196
	13	4.6	3.75	54	222	80	120
	14	4.7	1.50	40	150	120	90
	15	4.7	1.50	40	168	120	90
	16	4.5	2.25	24	125	120	90
	17	5.2	0.75	37	181	3640	522
	18	4.5	3.00	37	203	160	186
	19	4.6	3.00	48	231	200	246
	20	4.4	4.50	65	212	280	216
	21	4.0	6.75	47	281	320	222
	22	3.8	9.00	62	312	480	336
	23	3.8	6.75	159	315	760	444
	24	5.5	0.75	192	331	200	24
	25	7.5	0.00	107	275	4000+	600+
	26	7.8	0.00	58	281	2000+	600+
	27	7.9	0.00	47	256	2640	438

Table 30 (continued)

	28	7.9	0.00	35	247	4000+	600+
	29	7.9	0.00	58	295	3160	600+
	30	7.6	0.00	111	347	4000+	600+
	31	7.9	0.00	100	321	4000+	378
	32	8.0	0.00	94	290	4000+	600+
	33	8.0	0.00	94	287	4000+	600+
	34	7.8	0.00	115	347	4000+	600+
	35	7.9	0.00	103	381	4000+	522
	36	7.9	0.00	54	296	4000+	462
	37	7.7	0.00	52	265	4000+	600+
	38	7.8	0.00	91	295	4000+	600+
	39	7.9	0.00	62	256	4000+	600+
	40	7.9	0.00	111	321	4000+	432
	41	8.1	0.00	119	293	4000+	600+
	42	8.0	0.00	88	268	4000+	582
	43	8.0	0.00	37	250	4000+	600+
	44	8.2	0.00	94	284	4000+	516
	45	8.2	0.00	80?	244	4000+	600+
	46	8.2	0.00	100?	259	4000+	540
	47	8.3	0.00	80	262	4000+	492
	48	7.8	0.00	94	272	1800	516
	49	7.9	0.00	48	256	2040	540
	50	7.9	0.00	72	253	4000+	552
	51	7.8	0.00	94	265	1360	360
	52	7.7	0.00	132?	289	4000+	540
	53	7.7	0.00	159?	262	160	150
	54	7.8	0.00	80	222	1800	540
	55	7.8	0.00	142	287	1640	480
	56	7.9	0.00	107	284	120	132
	57	7.6	0.00	111	284	200	90
	58	6.3	--	128	256	1600	180
58-59'	59	4.2	--	80	228	4000+	600+
	59-64 coal	4.0	0.00	38?	63	480	54
	64-67	3.5	4.50	167	247	3040	600+

Table 31

Soiltest results for Upper Bakerstown coal overburden at Site FF.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
0-4"	A	4.7	6.00	69	265	1920	216
4-16"	B	4.2	6.00	52	194	520	78
16-26"	B	4.2	8.25	58	222	360	126
26-36"	C	4.5	8.25	91	309	280	204
36-51"	1	4.5	6.75	72	234	240	174
51-66"	2	4.6	5.25	77	241	280	168
15" increments	3	5.6	6.00	80	244	280	198
	4	4.7	6.75	82	290	560	318
	5	4.7	7.50	58	253	480	252
	6	4.7	2.25	60	222	360	186
	7	4.8	0.75	100	237	400	180
	8	4.6	6.00	80	275	720	378
	9	4.5	7.50	69	275	960	600+
	10	4.8	5.25	94	306	1200	600+
	11	5.3	1.50	107	296	1360	600+
	12	6.4	0	103	296	1280	576
	13	6.6	0	159	324	1720	570
	14	6.8	0	153	312	1880	552
	15	7.2	0	174	315	1840	462
	16	7.2	0	72	187	4000+	438
	17	7.1	0	97	156	3680	288
	18	7.0	0	97	175	4000+	312
	19	6.9	0	45	137	4000+	198
	20	7.5	0	107	253	4000+	600+
	21	7.2	0	94	228	4000+	600+
	22	7.5	0	50	250	4000+	576
	23	7.6	0	111	337	3649	600+

Table 31 (continued)

	24	7.8	0	123	331	4000+	600+
	25	7.8	0	100	309	4000+	600+
	26	7.1	0	123	272	4000+	600+
	27	7.7	0	107	281	4000+	600+
	28	7.2	0	85	296	4000+	600+
	29	7.3	0	103	327	2120	450
	30	7.2	0	97	341	1720	450
40-41.2'	31	6.5	0	667	256	1280	270

Table 32

Soiltest results for Lower Bakerstown coal overburden at Site FF-b.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
33.7-34.7'	1	6.6	0	19	56	1520	42
34.7-35.8'	2	6.3	0	31	78	2520	54
35.8-37.3'	3	6.4	0	38	109	1920	144
37.3-	4	7.8	0	37	300	4000+	396
-41.5'	5	8.0	0	34	268	4000+	324
41.5-	6	7.7	0	75?[a]	284	4000+	270
-55.5'	7	7.8	0	82?	334	3400	258
55.5-56.3'	8	7.7	0	91?	405	3280	426
56.3-57.9'	9	3.9	0	18	44	360	30
57.9-58.3'	10	6.5	0	48	253	480	48
58.3-60.4'	11	5.6	0	17	41	360	12

[a] uncertain results because of chemical interferences in test method.

Table 33

Soiltest results for Redstone coal overburden at Site HH.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
0-3"		4.4	4.50	65	334	2080	288
3-5"		4.0	6.75	47	200	440	84
5-8"		4.0	7.50	48	162	160	42
8-12"		4.0	6.00	45	131	120	36
12-18"		4.4	6.00	58	134	560	336
18-26"		4.3	5.25	48	125	320	234
26-46"		4.6	9.00	82	194	1240	582
46-48"		4.7	6.75	159	206	2760	600+
4-5'		4.8	5.25	294	215	4000+	600+
5-6'		5.0	3.00	308	194	4000+	600+
6-7'		5.1	2.25	200	162	3800	450
7-8'		7.0	0	174	153	4000+	600+
8-10'		7.4	0	137	109	4000+	600+
10-12'		4.7	4.50	80	204	3360	600+
12-14'		4.7	3.75	159	200	3320	600+
14-16'		5.1	2.25	216	178	4000+	600+
16-18'		5.5	1.50	142	162	4000+	600+
18-20'		7.0	0	97	146	3280	600+
20-21'	1	6.9	0	88	134	3280	498
21-22'	2	7.0	0	115	153	4000+	576
22-23'	3	7.7	0	45	106	4000+	414
	4	7.4	0	246	150	4000+	450
	5	7.7	0	75	131	4000+	390
	6	7.8	0	42	109	4000+	330
	7	7.8	0	45	103	4000+	312
	8	7.8	0	56	106	4000+	300
	9	7.9	0	52	93	4000+	204

Table 33 (continued)

10	7.8	0	238	103	4000+	150
11	7.3	0	256	134	4000+	360
12	7.3	0	256	156	4000+	462
13	6.8	0	200	156	4000+	528
14	7.8	0	62	118	4000+	390
15	7.8	0	256	137	4000+	510
16	7.7	0	300	140	4000+	600+
17	7.7	0	300	175	4000+	600+
18	7.7	0	246	181	4000+	594
19	7.6	0	296	187	4000+	564
20	7.8	0	294	203	4000+	600+
21	7.7	0	308	206	3920	600+
22	7.7	0	216	200	3440	600+
23	7.8	0	183	187	2720	600+
24	7.7	0	183	187	3000	600+
25	7.7	0	183	175	2720	600+
26	7.5	0	216	181	3360	600+
27	7.6	0	216	175	3360	600+
28	7.3	0	238	178	3600	600+
29	7.4	0	238	200	4000+	600+
30	7.4	0	246	178	3680	600+
31	7.0	0	216	156	4000+	600+
32	7.1	0	294	146	4000+	600+
33	7.5	0	238	244	4000+	600+
34	7.8	0	192	228	3640	600+
35	7.5	0	174	218	2960	600+
36	7.0	0	216	209	3840	600+
37	7.4	0	216	209	2880	480
38	6.4	-	308	212	2320	378
39	6.5	0	216?	228	2800	528
40	7.4	0	183	275	2840	600+
41	7.5	0	174?	287	3200	600+
42	7.0	0	200?	262	2680	492
43	5.6	0	294?	231	2720	372

Table 33 (continued)

44	3.7	2.25	246	178	1840	288
45	4.3	0	128	100	920	132
46	5.1	0	137	112	920	150
47	4.2	0	119	96	760	108
48	2.5	8.25	159?	181	4000+	600+
49	6.1	0	342?	272	4000+	600+
50	6.3	0	308	262	4000+	600+
51	7.4	0	159	297	4000+	600+

Table 34

Sewell coal overburden at Site NN-b.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
	1	4.4	9.00	29	231	240	168
	2	4.5	9.00	38	287	280	258
	3	4.6	4.50	42	287	160	144
	4	4.6	5.25	54	359	80	102
	5	4.7	5.25	47	327	40	90
	6	4.7	4.50	75	327	120	156
	7	4.7	3.00	60	321	40	72
	8	4.8	2.25	67	321	40	96
	9	4.7	2.25	60	306	80	84
	10	4.7	3.00	100	312	280	120
	11	4.7	2.25	111	324	360	264
	12	5.1	0.75	153	306	960	342
	13	4.7	3.00	85	341	280	240
	14	5.0	0.75	97	306	600	534
	15	5.8	-	147	275	960	600+
	16	5.6	0.75	159	315	1320	600+
	17	5.1	0.75	107	324	800	600+
	18	4.9	0.75	80	296	720	600+
	19	5.1	1.50	94	344	960	600+
	20	4.9	2.25	75	350	600	600+
	21	5.0	2.25	85	321	560	516
	22	5.1	1.50	97	337	720	600+
	23	5.6	0.75	159	224	920	600+
	24	5.8	-	183	312	1360	600+
	25	6.6	0	67	337	2160	600+

Table 34 (continued)

26	7.0	0	700?	356	2280	600+
27	6.2	0.75	238	275	1840	600+
28	6.4	-	200	778	1880	600+
29	6.3	-	238	272	1440	600+
30	6.7	0	200	278	1600	594
31	6.8	0	294?	306	1420	600+
32	6.6	0	246	253	1760	600+
33	6.1	0.75	174	222	1400	600+
34	6.0	0.75	167	228	1280	600+
35	5.9	0.75	159	222	1280	600+
36	6.0	0.75	111	194	1160	600+
37	6.3	0.75	200	234	1560	594
38	6.7	0	256	253	1760	600+
39	6.8	0	256	272	1760	582
40	7.1	0	294	324	2160	600+
41	7.2	0	246?	306	2080	558
42	7.2	0	148?	372	2240	588
43	7.4	0	216?	350	2160	510
44	7.5	0	183?	356	2120	456
45	7.5	0	238?	350	2000	432
46		0				
47	7.3	0	183?	344	1800	444
48	7.3	0	159?	390	1920	540
49	7.2	0	200?	396	1960	564
50	7.3	0	183?	418	2080	552
51	7.4	0	238?	418	2040	462
52	7.1	0	246?	384	1640	348
53	7.1	0	238?	430	2280	480
54	7.1	0	256?	393	1920	456
55	7.1	0	238?	390	1680	384
56	6.5	0	294?	341	2040	384
57	6.8	0	238	372	2160	420
58	7.0	0	294?	375	2320	402

Table 34 (continued)

59	6.9	0	216?	375	2560	408
60	7.1	0	216?	372	2720	396
61	7.0	0	238?	375	2840	372
62	7.2	0	256?	337	2120	288
63	7.3	0	192?	362	2440	354
64	7.0	0	372	359	2280	372
65	6.5	0	238	350	1640	396
66a	6.4	0	238	324	1200	330
66b	6.3	-	216	318	1120	330

Table 35

Soiltest results for Elk Lick coal overburden at Site PP.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
0-3"	A hor	4.3	8.25	40	184	4000+	282
0-1'	+20	4.4	5.25	35	134	440	42
1-2'	+19	5.0	3.0	45	165	1160	102
2-3'	+18	6.5	0	82	181	3160	264
3-4'	+17	6.8	0	102	194	3280	282
4-5'	+16	7.0	0	107	184	3760	318
5-6'	+15	7.1	0	123	187	4000+	402
6-7'	+14	6.9	0	107	172	4000+	378
7-8'	+13	6.9	0	103	168	4000+	342
8-9'	+12	7.0	0	119	172	4000+	432
9-10'	+11	7.2	0	246	228	4000+	372
10-11'	+10	6.9	0	300	225	4000+	312
11-12'	+9	4.8	0	54	178	1120	72
12-13'	+8	7.3	0	111	178	4000+	408
13-14'	+7	7.1	0	153	259	4000+	450
14-15'	+6	7.1	0	147	250	4000+	474
15-16'	+5	7.1	0	147	250	4000+	474
16-17'	+4	7.2	0	142	191	4000+	390
17-18'	+3	7.3	0	132	194	4000+	366
18-18.5'	+2	7.3	0	142	203	4000+	378
18.5-19'	+1	7.7	0	38	175	4000+	354
19-20'	1	7.3	0	111	191	4000+	462

Table 35 (continued)

20-21'	2	7.6	0	40	165	4000+	474
21-22'	3	7.7	0	100	153	4000+	372
22-23'	4	7.2	0	91	156	3520	144
23-24'	5	7.8	0	192	150	4000+	132
24-25'	6	7.7	0	67	131	4000+	102
25-26'	7	7.8	0	60	150	4000+	78
26-27'	8	7.8	0	40	121	4000+	90
27-28'	9	7.5	0	35	121	4000+	84
28-29'	10	7.4	0	107	150	4000+	372
29-30'	11	7.5	0	85	168	4000+	288
30-31'	12	7.6	0	38	134	4000+	192
31-32'	13	7.7	0	38	162	4000+	228
32-33'	14	7.9	0	183	175	4000+	600+
33-34'	15	8.0	0	192	156	4000+	600+
34-35'	16	7.5	0	142	162	4000+	600+
35-36'	17	7.9	0	153	150	4000+	390
36-37'	18	7.9	0	91	131	4000+	198
37-38'	19	7.9	0	58	118	4000+	312
38-39'	20	7.9	0	103	131	4000+	600+
39-40'	21	8.1	0	132	146	4000+	600+
40-41'	22	8.0	0	128	146	4000+	600+
41-42'	23	7.9	0	159	128	4000+	468
42-43'	24	7.9	0	183	140	4000+	600+
43-44'	25	7.7	0	91	162	4000+	600+
44-45'	26	7.9	0	137	146	4000+	600+
45-46'	27	6.3	0	94	209	4000+	600+
46-47'	28	7.3	0	91	228	4000+	468
47-48'	29	6.9	0	85	247	3560	432
48-49'	30	7.0	0	107	296	3160	372
49-50'	31	7.7	0	167	362	3280	366
50-51'	32	7.8	0	246	353	4000+	354

Table 35 (continued)

51-52'	33	7.7	0	246	337	3360	336
52-53'	34	7.8	0	147	344	2480	306
53-54'	35	7.6	0	142	331	4000+	360
54-55'	36	7.7	0	35	312	4000+	420
55-56'	37	7.8	0	40	296	4000+	396
56-57'	38	7.8	0	85	331	4000+	438
57-58'	39	7.5	0	128	359	4000+	378
58-59'	40	7.1	0	123	365	4000+	270

(Includes top 6" of coal)

Table 36

Soiltest results for Lower Kittanning coal overburden at Site O.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
0-7"	0-7	4.4	6.00	38	197	400	48
0.5-2'	7+28	4.1	6.00	43	168	160	36
2-4'	34-36	4.3	5.25	42	178	160	114
4-8'	30-34	4.2	4.50	35	156	240	228
6-8'	30-32	4.4	6.00	54	134	360	258
8-10'	28-30	4.6	3.00	48	146	280	186
10-12'	26-28	4.5	2.25	48	93	80	60
12-14'	24-27	4.4	2.25	45	100	80	42
14-16'	22-24	4.5	2.25	34	118	40	42
16-18'	20-22	4.6	1.50	45	112	40	36
18-20'	18-20	4.7	1.50	38	100	240	114
20-22'	16-18	4.5	4.50	23	128	560	234
22-24'	14-16	4.7	2.25	22	137	640	234
24-26'	12-14	4.8	3.00	23	128	680	216
26-28'	10-12	4.8	5.25	32	143	960	300
28-30'	8-10	4.5	2.25	42	150	560	168
30-32'	6-8	4.4	4.50	48	109	120	42
32-34'	4-6	4.7	0.75	40	112	400	138
34-36'	2-4	4.6	2.25	43	128	360	168
36-37'	1-2	4.5	3.75	26	172	640	300
36-38'	0-2	4.7	1.50	38	184	480	222
38-39'	1	4.3	3.00	23	175	360	222
39-40'	2	4.8	1.50	27	178	480	306

Table 36 (continued)

3	5.2	0.75	69	181	600	306
4	7.3	0	216	272	1640	480
5	7.4	0	200	281	1720	504
6	7.5	0	238	284	1680	498
7	7.6	0	174	287	2040	576
8	7.0	0	238	244	1400	426
9	7.7	0	123	209	2080	600+
10	7.2	0	192	241	1200	408
11	7.1	0	238	256	1240	402
12	7.5	0	200	321	1760	534
13	7.3	0	153	309	1160	492
14	7.4	0	153	284	1320	516
15	7.4	0	159	268	1280	480
16	7.2	0	174	256	1160	408
17	6.9	0	153	262	1240	450
18	7.4	0	119	284	1320	438
19	7.3	0	137	290	1360	450
20	7.3	0	200	293	1640	444
21	7.5	0	200	296	1760	426
22	7.5	0	238	281	1680	384
23	7.8	0	167	275	1920	426
24	7.8	0	137	306	2200	480
25	7.7	0	153	315	2840	504
26	7.8	0	183	321	2880	522
27	7.7	0	137	327	2880	528
28	-	-	-	-	-	-
29	7.8	0	147	327	3080	504
30	7.9	0	167	334	3480	570
31	7.9	0	123	324	4000+	600+
32	7.8	0	132	318	4000+	600+
33	7.8	0	159	321	3200	590

Table 36 (continued)

	34	-	-	-	-	-	-
	35	6.2	0	294	315	2680	384
	36	6.4	0	123	387	2040	396
	37	4.5	0.75	308	265	2800	348
	38	5.7	0.75	115	247	1840	354
	39	5.6	0	119	250	1520	306
	40	6.5	0	100	331	1600	342
79-80'	41	3.0	5.25	31	191	1360	270
80-	Lower Kittanning coal seam						

Table 37

Soiltest results for Lower Kittanning coal overburden at Site B-B', la.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
3-4'	BB 1C	4.5	1.50	17	96	1480	474
	2	4.3	0.75	21	72	1480	186
	3	3.8	0.75	18	69	1000	174
	4	4.0	--	20	60	2000	150
	5	4.2	0.75	23	78	1800	240
	6	4.7	--	24	35	2400	186
	7	3.9	0.75	19	84	2880	246
	8	4.4	--	22	44	640	54
	9	3.7	0.75	25	125	760	54
	10	4.6	--	21	78	960	48
	11	4.7	--	21	38	2240	54
	12	4.9	--	19	38	3080	114
	13	5.4	--	18	56	520	30
	14	4.8	--	25	47	3120	78
	15	4.7	--	19	56	4000+	372
	16	5.0	--	23	81	1040	78
	17	4.2	0.75	20	66	2400	372
	18	3.3	2.25	21	168	4000	246
	19	5.4	--	24	96	360	168
	20	5.0	--	20	47	3240	366
	21	4.7	0.75	14	63	4000+	372
	22	4.3	0.75	18	90	1040	78
	23	4.6	--	20	41	800	54
	24	4.8	--	21	47	4000+	340
	25	4.7	--	18	56	1840	60
	26	4.4	--	16	41	180	6
	27	4.4	0.75	17	44	120	6

Table 37 (continued)

28	4.4	0.75	20	44	120	12
29	3.7	0.75	16	63	280	18
30C	3.0	5.25	25	53	440	60
31	2.8	4.50	23	159	640	252
32	2.6	7.50	31	168	800	372
33	2.7	5.25	31	194	760	360
34	2.8	6.75	45	253	840	348
35	2.9	7.50	56	256	720	336
36	2.9	8.25	132	306	1320	402
37	3.5	6.75	308?	384	3200	510
38	4.1	2.25	294	347	2400	390
39	3.8	3.00	256?	362	2280	402
40	5.3	1.50	192?	347	2360	492
41	6.1	0.75	246?	321	2760	492
42	6.8	0	142?	300	3080	474
43	6.3	0	246?	315	1720	444
44	4.8	1.50	137	347	1240	420
45	4.9	0.75	97	337	1050	414
46	5.0	0.75	72	334	800	360
47	4.8	0.75	91	344	1000	390
48	4.9	0.75	256?	344	1720	354
49	5.0	1.50	300?	331	2360	348
50	5.1	0.75	159	347	1320	384
51	5.2	0.75	123	331	1080	360
52	5.0	1.50	115	347	1120	378
53	4.9	1.50	75	350	840	372
54	4.8	0.75	72	359	840	372
55	4.8	0.75	100	353	1000	372
56	4.4	1.50	77	302	840	366
57	4.5	1.50	75	359	760	336
58	4.5	1.50	72	281	560	234
59	4.6	0.75	80	318	640	276
60	4.6	1.50	77	278	560	228

Table 37 (continued)

	61		4.8	1.50	75	293	640	276
	62		4.7	0.75	82	300	680	288
	63		4.8	0.75	80	296	640	276
	64		4.9	0.75	80	309	640	288
	65		5.0	0.75	65	300	640	300
	66		4.7	1.50	60	278	520	234
	67		3.3	4.50	56	247	640	288
	68		3.5	1.50	119	187	640	162
	69		3.5	1.50	94	206	600	162
	70	coal	3.9	0.75	69	165	400	108
	71	coal	3.7	1.50	128	225	760	186
	72	coal	3.6	1.50	65	197	480	138
	73	coal	3.9	0.00	94	134	640	96
	74	coal	4.1	0.00	45	72	560	42
	75	coal	3.5	1.50	43	187	720	150
	76		3.2	5.25	65	184	720	222
	77		2.8	6.75	37	153	720	300
-78'	78		3.2	3.75	40	290	720	294

Table 38

Soiltest results for Lower Kittanning coal overburden at Site B-B', lb.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
27-28'	1	4.3	2.25	58	137	440	48
	2	4.3	2.25	54	140	120	24
	3	4.2	2.25	54	131	80	24
	4	4.2	3.00	65	109	40	12
	5	4.2	3.00	69	181	120	72
	6	4.2	3.00	67	278	240	162
	7	4.2	2.25	65	309	360	210
	8	4.1	2.25	60	287	320	186
	9	4.3	1.50	65	278	320	210
	10	4.2	2.25	67	306	400	240
	11	4.3	2.25	69	300	360	204
	12	4.1	3.00	67	234	1520	234
	13	4.2	3.75	65	347	720	222
-43'	14	3.9	5.25	69	315	600	240
	15	Lower Kittanning coal seam					

Table 39

Soiltest results for Lower Kittanning coal overburden at Site B-B', 1c.

				per Thousand Tons of Material			
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
0-1'	1	4.5	1.50	42	87	160	0
	2	4.7	0.75	37	93	80	0
	3	5.0	0.75	37	96	80	0
	4	5.0	0	37	115	80	6
	5	7.3	0	52	175	1040	252
	6	6.2	0	45	159	200	102
	7	6.7	0	42	172	160	108
	8	5.9	0	47	178	160	108
	9	5.6	0	37	131	160	60
	10	5.7	0	37	115	120	30
	11	5.9	0	37	78	80	0
	12	5.8	0	34	84	80	0
	13	5.9	0	31	63	160	0
	14	6.0	0	42	66	160	0
	15	5.7	0	29	69	120	0
	16	5.8	0	32	81	120	0
	17	6.0	0	48	100	120	0
	18	6.0	0	52	125	120	0
	19	6.4	0	48	115	80	0
	20	6.5	0	47	125	160	0
	21	6.0	0	47	137	160	0
	22	6.1	0	54	193	160	0
	23	6.1	0	54	137	160	0
	24	5.8	0	60	134	120	0
	25	7.0	0	69	312	560	204
	26	6.0	0	72	309	480	198
	27	6.0	0	69	327	480	198
	28	6.2	0	77	344	520	228

Table 39 (continued)

	29	5.1	0	72	321	480	198
	30	4.4	2.25	75	331	520	204
	31	4.1	3.75	72	321	440	180
	32	3.9	3.75	72	324	480	186
	33	4.1	3.00	60	309	480	186
	34	4.0	4.50	65	347	400	180
	35	4.0	3.75	65	344	400	186
-42'	36	7.0	0	67	353	440	216

46'- Lower Kittanning coal seam

Table 40

Soiltest results for Pittsburgh coal overburden at Site A-A', 17a.

			Tons	per Thousand Tons of Material Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
18-20'	17	7.3	0	167	191	3280	408
	16	7.7	0	320	262	4000+	486
	15	7.8	0	256	334	4000+	600+
	14	7.6	0	300	337	4000+	582
	13	4.2	2.25	192	281	3200	372
	12	7.6	0	20	250	4000+	426
	11	8.2	0	13	156	4000+	204
	10	3.1	0	13	93	4000+	192
	9	8.2	0	14	121	4000+	342
	8	8.2	0	9	87	4000+	222
	7	8.2	0	12	138	4000+	276
	6	7.9	0	12	200	4000+	264
	5	7.6	0	26	250	4000+	492
	4	7.9	0	97	334	2920	420
	3	7.8	0	115	337	3680	510
	2	7.5	0	38	265	4000+	516
50-52'	1	6.6	0	69	253	3120	396
52'-	Coal	5.3	0	12	25	1680	30

Table 41

Soiltest results for Pittsburgh coal overburden at Site A-A', 17b.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
3-4'	1	6.3	-	91	156	600	168
	2	6.4	-	88	121	480	144
	3	6.4	-	94	128	640	180
	4	6.4	-	97	137	560	168
	5	6.4	-	91	143	520	162
	6	6.2	-	88	140	520	168
	7	5.8	-	91	162	640	198
	8	6.1	-	50	112	600	168
	9	6.1	-	69	131	2360	258
	10	5.9	-	60	121	1960	228
	11	5.9	-	52	121	2920	324
	12	5.5	0.75	47	191	2400	438
	13	5.4	0.75	115	200	3120	600+
	14	5.6	-	174	203	3760	600+
	15	5.9	-	183	203	3320	492
18-19'	16	7.0	0	167	93	2800	510

Table 42

Soiltest results for Pittsburgh coal overburden at Site A-A', 17c.

			Tons per Thousand Tons of Material	Pounds per Thousand Tons of Material			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
26-27'	1	7.8	0	17	244	4000+	408
	2	8.0	0	21	259	4000+	480
	3	8.0	0	62	296	4000+	516
	4	8.1	0	20	259	4000+	432
	5	8.2	0	14	134	4000+	222
	6	8.2	0	12	93	4000+	210
	7	8.2	0	12	134	4000+	288
	8	8.3	0	12	134	4000+	360
	9	8.2	0	8	41	4000+	198
	10	8.2	0	10	75	4000+	270
	11	8.2	0	7	69	4000+	240
	12	8.1	0	6	50	4000+	162
	13	8.2	0	7	93	4000+	174
	14	8.0	0	7	121	4000+	192
40-41'	15	7.9	0	5	184	4000+	288

Table 43

Soiltest results for Pittsburgh coal overburden at Site OO.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
	1	7.3	0	56	234	4000+	600+
	2	7.4	0	54	275	4000+	600+
	3	7.4	0	56	275	4000+	600+
	4	7.5	0	167	331	4000+	600+
	5	7.9	0	85	290	4000+	600+
	6	8.1	0	128	306	4000+	600+
	7	8.1	0	54	281	4000+	534
	8	8.1	0	132	312	4000+	600+
	9	8.0	0	94	284	4000+	600+
	10	7.4	0	50	287	4000+	600+
	11	8.2	0	42	290	4000+	534
	12	8.2	0	38	303	4000+	564
	13	8.1	0	42	350	4000+	600+
	14	8.4	0	42	344	4000+	600+
	15	8.2	0	40	344	4000+	600+
	16	8.1	0	40	344	4000+	600+
	17	8.1	0	42	315	4000+	600+
	18	8.1	0	40	318	4000+	600+
	19	8.2	0	58	312	4000+	600+
	20	8.3	0	67	303	4000+	600+
	21	8.2	0	58	300	4000+	600+
	22	8.1	0	47	296	4000+	600+

Table 43 (continued)

23	7.9	0	80	300	4000+	600+
24	8.1	0	56	287	4000+	600+
25	7.9	0	56	296	4000+	600+
26	8.4	0	45	275	4000+	600+
27	8.2	0	42	268	4000+	600+
28	8.2	0	47	265	4000+	600+
29	8.1	0	72	281	4000+	600+
30	7.9	0	80	262	4000+	600+
31	8.1	0	43	247	4000+	600+
32	8.1	0	32	234	4000+	600+
33	-	-	-	-	-	-
34	7.7	0	153	303	4000+	600+
35	4.8	1.50	183	303	4000+	600+

Table 44

Soiltest results for Sewell coal overburden at Site MM.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
2-3'		5.0	0.75	35	44	200	30
3-4'		5.9	0	20	81	520	24
4-5'		5.7	0	19	69	120	18
5-6'		5.4	0	18	84	40	12
6-7'		5.2	0.75	17	100	80	18
7-8'		5.1	0.75	14	87	40	12
8-9'		5.1	0.75	15	84	40	12
9-10'		5.5	0	21	75	40	12
10-11'		5.0	0.75	17	78	40	12
11-12'		5.6	0	22	87	40	18
12-13'		5.7	0	19	78	40	18
13-14'		5.0	0.75	34	93	40	12
14-15'		5.3	0.75	21	84	80	12
15-16'		4.8	3.00	32	112	80	24
16-17'		5.4	0	23	81	120	30
17-18'		5.2	0.75	17	84	80	18
18-19'		5.1	1.50	25	93	130	24
19-20'		5.3	0.75	19	87	80	24
20-21'		5.1	0.75	43	106	160	42
21-22'		5.1	2.25	38	121	120	30
22-23'		5.6	0	22	63	80	18
23-24'		5.3	0.75	14	81	80	24
24-25'		5.4	0	22	106	80	24
25-25.5'		5.2	0.75	24	109	80	18

Table 45.
Soiltest results for Sewell coal overburden at Site NN-a.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
	1	7.1	0	174?	259	1200	348
	2	7.2	0	183?	303	1760	450
	3	7.4	0	142?	287	1520	390
	4	7.1	0	174?	296	1280	420
	5	7.1	0	200?	290	1160	378
	6	7.0	0	192?	337	1320	600+
	7	7.0	0	200?	353	1320	600+
	8	7.1	0	200	259	1400	600+
	9	7.0	0	192	353	1240	468
	10	7.0	0	183	309	1040	324
	11	7.0	0	256	327	1280	384
	12	7.1	0	216	327	1280	390
	13	6.5	0	246?	324	1640	408
	14	6.6	0	294?	359	1960	486
	15	6.9	0	300?	341	2080	414
	16	6.9	0	300?	319	2280	444
	17	7.2	0	294?	350	2920	414
	18	7.1	0	294?	306	3120	366
	19	7.2	0	300?	293	2720	348
	20	7.0	0	246?	272	1800	294
	21	5.2	-	192	284	1040	366

Table 46

Soiltest results for Upper Freeport and Lower Kittanning coal overburden at Site B-B', 16.

			Tons per Thousand Tons of Material	Pounds per Thousand Tons of Material			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
18-23.6'	1	7.0	0	62?	87	680	42
23.6-30	2	6.3	0	77?	150	720	186
30-35	3	7.3	0	111?	187	520	84
35-37.3	4	7.6	0	132?	181	4000+	600+
37.3-39	7	6.7	0	77?	209	960	288
39-40	8	6.2	0	88?	234	640	168
40-40.7	5	7.0	0	77?	178	640	144
40.7-40.9	9	5.7	0	183?	228	1080	114
40.9-42.3	10	5.7	0	200	231	1000	228
42.3-45	11	6.2	0	94	212	840	192
45-46	6	7.4	0	128?	197	4000+	600+
57.1-62.2	Upper Freeport coal seam						
75-80	12	7.8	0	52	284	4000+	408
80-82.9	13	7.6	0	111?	315	4000+	594
82.9-85	14	7.5	0	167?	402	1880	372
85-90	15	7.4	-	142?	334	1480	324
90-91	16	7.4	0	153?	281	2040	384
91-96	17	7.3	0	147?	337	1760	360
96-97.5	18	7.7	0	256	527	2680	558
97.5-98	19	7.4	0	246	468	2320	438
98-99	20	7.4	0	294	455	2560	474
99-100	21	7.4	0	192	440	2960	600+
100-101	22	7.6	0	183	496	3280	600+
101-101.6	23	3.4	5.25	159?	347	2080	336
101.6-104.5	24	7.4	0	147	399	2360	498

Table 46 (continued)

104.5-106	25	6.2	0	137	418	2440	522
106-107	26	7.6	0	137	433	4000+	600+
107-108	27	7.6	0	137	462	1560	354
108-109.5	28	7.8	0	128	440	4000+	426
109.5-111.5	29	7.9	0	65	375	4000+	348
111.5-113	30	7.7	0	159?	437	2160	306
113-115	31	7.7	0	200?	399	1840	240
115-117	32	7.7	0	256?	396	2400	246
117-120	33	7.5	0	200?	368	1640	204
120-122	34	7.8	0	246?	415	2360	282
122-125	35	7.6	0	142?	321	1400	204
125-130	36	7.7	0	128?	275	4000+	600+
130-135	37	7.9	0	142?	334	4000+	600+
135-140	38	7.9	0	56	250	4000+	240
140-145	39	7.9	0	132?	287	4000+	312
145-149.5	40	7.9	0	159?	303	1920	174
149.5-150	41	7.8	0	123?	312	4000+	474

Table 47

Soiltest results for Lower Kittanning coal overburden at Site B-B', 18.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
272-275.5'	Lower Freeport coal seam						
277.5-278.5	1	7.0	0.00	103?	408	1880	288
278.5-280	2	4.2	3.00	56?	359	1240	420
280-281	3	7.1	0.00	91?	362	1920	546
281-282	4	7.3	0.00	115?	496	2840	414
282-	5	7.1	0.00	82?	433	1680	366
	6	7.3	0.00	107?	496	1880	378
	7	7.2	0.00	147	499	2040	408
-296	8	7.1	0.00	159?	496	2000	402
296-298.5	9	6.8	0.00	159?	440	3040	342
298.5-299	10	7.4	0.00	111?	143	3440	600+
302.5-303.5	12	7.3	0.00	52?	156	4000+	180
319.5-321.5	13	7.6	0.00	72?	218	4000+	600+
322-323	14	7.0	0.00	52	312	4000+	600+
323-326	15	7.2	0.00	80?	225	4000+	600+
326-326.5	16	7.0	0.00	137?	433	4000+	600+
326.5-	17	7.9	0.00	48	321	4000+	462
-333.5	18	7.6	0.00	119?	384	4000+	600+
334-336	19	7.6	0.00	103?	390	4000+	528
336-339.5	20	7.6	0.00	132?	412	4000+	576
339.5-	21	7.6	0.00	128?	396	4000+	564
	22	7.6	0.00	128?	446	4000+	582
	23	7.7	0.00	52	359	4000+	390

Table 47 (continued)

	24	7.6	0.00	132	458?	3760	516
	25	7.7	0.00	119	387?	4000+	600+
	26	7.6	0.00	128	359?	3000	462
-354	27	7.4	0.00	123	384?	4000+	540
354-356	28	7.4	0.00	132	387?	4000+	600+
356-	29	7.2	0.00	107	384?	3600	600+
359.5-	Upper Kittanning coal seam position (3")						
-360	30	7.3	0.00	128	437?	2680	564
366-	31	7.4	0.00	123	421?	2520	600+
-372	32	7.0	0.00	119?	412	2240	594
376-	33	7.4	0.00	147?	381	2760	420
-379	34	7.5	0.00	115?	306	5760	420
379-380	35	7.7	0.00	58?	241	9120	252
380-	36	7.5	0.00	137	412	3080	420
-385	37	7.6	0.00	132	402	2880	384
385-386.5	38	7.5	0.00	153	331	3160	390
386.5-	39	7.4	0.00	153	437	2720	432
-390.5	40	7.4	0.00	132	446	2480	468
390.5-	41	7.4	0.00	142	443	2280	468
	42	7.4	0.00	137	418	2800	504
-399.5	43	7.2	0.00	159	446	2440	378
400-	44	7.3	0.00	216	499	2640	402
	45	7.2	0.00	238	509	2880	432
-406	46	7.3	0.00	216	462	3440	384

Site B-B', la is a case where a near-surface sandstone has retained significant percentages of sulphur and has failed to show typical color changes and other evidences of near-surface weathering. Laboratory measurements have indicated that this sandstone is toxic or potentially toxic and should be buried under favorable mudrock occuring deeper in the section.

PLANT NUTRIENT STATUS OF OVERBURDEN MATERIALS

Utilization of agricultural soil tests to evaluate the plant nutrient status of minesoils and coal overburdens requires a somewhat different interpretation of the analytical results than when normal agricultural soils are considered.

Although nitrogen is rarely included in a soil test analysis, the need for adding this element to disturbed land areas in universal where revegetation is expected, and can be accomplished by periodic nitrogen fertilization or inclusion of sufficient legumes.

Data from numerous samples analyzed by the West Virginia University Soil Testing Laboratory indicated that the store of plant available potassium in most unweathered overburden materials is adequate to support vegetation except where intensive agricultural cropping will be practiced. Petrographic examination of samples from various Carboniferous sediments also confirmed the presence of significant amounts of muscovite mica, which releases potassium slowly upon weathering to hydrous mica or vermiculite.

Analyses for plant-available phosphorus, calcium, magnesium, and trace elements can be affected by interactions between the samples of overburden or minesoil and the chemical extractant used to evaluate the nutrient availability. Materials containing as little as one to two percent calcium carbonate can neutralize the acid contained in most soil test extractants used in the eastern United States. The neutralized extractant cannot be expected to remove the proportionate amounts of nutrients that have been correlated with field responses. Plant available phosphorus, calcium, and magnesium will be inaccurately estimated with such an extractant.

In experiments with acid minesoils in eastern Kentucky it was noted that plant responses to phosphorus agreed better with available phosphorus as extracted by the Bray (acid ammonium fluoride) extraction than by extraction with a dilute acid mixture of hydrochloric and sulphuric acid (Berg, 1967). In West Virginia it has been noted, repeatedly, that some acid minesoils and overburden samples extracted with a dilute acid mixture give false colors or precipitates when the extracting solution is treated with vanadate to develop yellow colors that indicate phosphorus concentrations. This experience and other evidences of ferrous and ferric iron in acid soil solutions support the conclusion that acid-soluble iron is responsible for inaccurate indications of available phosphorus in some acid minesoils.

With near-neutral and alkaline minesoils it has been observed in West Virginia that acid extractions sometimes give unreliable indications of available phosphorus. Such unreliable results with acid extractions from carbonate-rich minesoils are predictable, theoretically, in some cases because excess carbonates are known to neutralize the acid extractant, preventing normal acid solubilization, whereas with neutral minesoils containing little or no carbonates, the full strength acid will partially dissolve the apatite which often occurs in variable rock types but in forms that are largely unavailable to plants. Considering these and other difficulties of extracting available phosphorus with standard acid soiltest methods commonly used with undistrubed soils of humid regions, it was decided to introduce the sodium bicarbonate extraction method which has been shown to correlate well with plant response in western United States, both with acid and with alkaline soils (Olsen, et al, 1954). Since minesoils consist of variable, physically disrupted rock types, many of which contain fresh rock minerals including carbonates and apatites, it is logical to expect that the sodium bicarbonate method will be an improvement over previously used soiltests in this region.

Amounts of available phosphorus extracted from overburdens and minesoils by three chemical methods are not given in detail, but in general, the amount extracted by the dilute acid mixtures has been more erratic and higher than that extracted by sodium bicarbonate or dilute acid plus ammonium fluoride, using minesoils with a pH range from 3.0 to 7.9. Sodium bicarbonate phosphorus was, as expected, higher for minesoils of pH above 6.5 than was the ammonium fluoride extractable P. This is reasonable because the ammonium fluoride is dissolved in acid and was designed and standardized with acid soils. With acid minesoils, on the other hand, a satisfactory correlation was obtained between sodium bicarbonate and ammonium fluoride methods as shown in Table 48.

A correlation coefficient of 0.86, indicating that 74% of phosphorus variation by either method is accounted for by the other method, is a usable relationship, regardless of which method is considered as the standard.

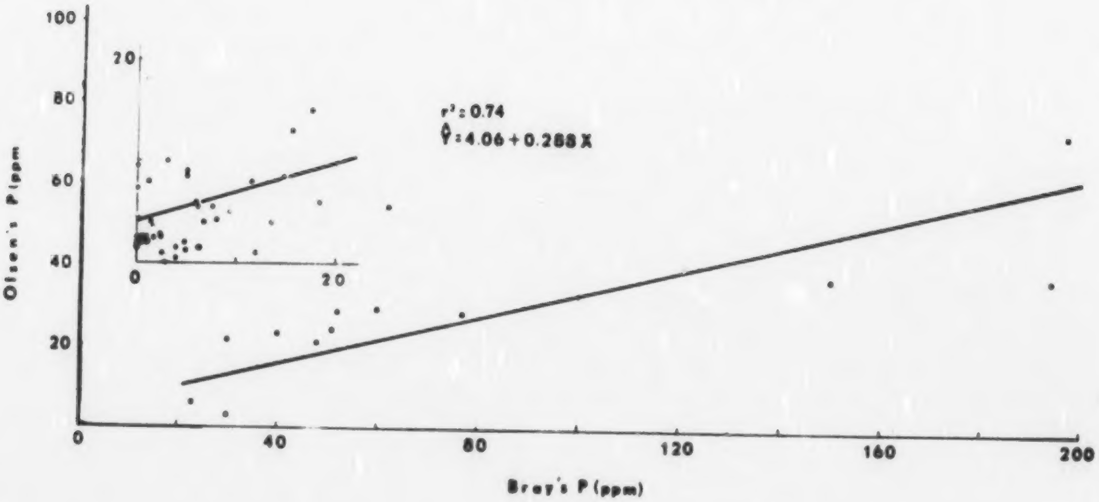


FIGURE 17. RELATIONSHIP BETWEEN SODIUM BICARBONATE EXTRACTABLE (OLSEN'S) AND ACID AMMONIUM FLUORIDE EXTRACTABLE (BRAY'S) PHOSPHORUS IN OVERBURDEN SAMPLES HAVING A 1:1 pH OF LESS THAN 6.5.

Table 48. CORRELATION COEFFICIENTS BETWEEN AMOUNTS OF AVAILABLE PHOSPHORUS EXTRACTED FROM OVERBURDEN MATERIALS BY THREE EXTRACTANTS (OLSEN AND DEAN, 1965): (1) (NELSON, et al, 1953) ()(0.05 N HCl + 0.025 N H_2SO_4); (2) (BRAY, et al, 1945) (0.025 N HCl + 0.03 N NH_4F); AND (3) (OLSEN, et al, 1954) (0.5 M $NaHCO_3$ AT pH 8.5)

	pH of samples was less than 6.5			pH of samples was greater than 6.5		
	Nelson	Bray	Olsen	Nelson	Bray	Olsen
Nelson	-	0.48**	0.47**	-	0.37*	0.21
Bray	-	-	0.86**	-	-	0.036

Published literature on the forms and relative availability of soil phosphorus will not be reviewed in detail in this report. However, there are fundamental reasons to believe that sodium bicarbonate is at least as satisfactory an extractant as acid ammonium fluoride for acid minesoils. For neutral or alkaline minesoils there should be no serious doubts about validity of sodium bicarbonate extraction, in contrast to acid extractions, which have been consistently unsatisfactory with alkaline soils.

Improved testing of minesoils for available phosphorus promises improved revegetation, reduced costs by avoiding phosphorus fertilization which is not needed, and more accurate longtime maintenance treatments on established vegetation devoted to variable uses.

Calcium and magnesium commonly are present in amounts sufficient for plant survival in minesoil and overburden materials that have appreciable base content as measured by the Neutralization Potential procedure. Acid materials, when limed sufficiently to insure successful revegetation, will also then usually have sufficient amounts of calcium and magnesium, particularly if dolomitic lime, where the ratio of calcium to magnesium approaches 20 to 1 or higher, is used.

In general, sandstone derived minesoils and sandstone overburdens can be expected to have the most intense nutrient deficiencies for successful revegetation with forages. On the other hand, fine-grained rock materials (mudrock, shale, limestone) present the most complex situations for nutrient status evaluation.

Micronutrients can generally be considered to be sufficient in fine grain sediments, however specific investigations must be made if a trace element deficiency or toxicity is suspected in a particular minesoil revegetation problem.

Previous work at this laboratory (West Virginia University, 1971a) established accuracy of the Woodruff buffer method of determining the immediate lime requirement of acid minesoils when compared to the direct calcium hydroxide titration method; however the modified adjustment factor built into the Woodruff method in West Virginia soiltests has been 1.5 times that used by Woodruff, and needs to be reduced to provide a direct immediate lime requirement estimation for minesoils. If the sample contains appreciable amounts of pyrite (greater than 0.1%) that will produce acid upon breakdown of the rock in minesoil, lime will be necessary to neutralize this acidity. If measurement of Neutralization Potential shows the presence of insufficient natural bases, an estimate of lime requirement can be made by the equation:

$\% S_{total} \times 15 =$ Tons of $CaCO_3$ needed/Thousand tons of material. (1)

The figure thus derived is about one-half of that theoretically required as calculated from pyritic sulphur content. On a practical basis, five tons per acre is the highest rate normally recommended for a surface application. If the lime is to be incorporated into the minesoil to some depth, as much as ten tons per acre may be recommended. If the material under evaluation is from the weathered rock zone, as indicated by a color chroma of 3 or greater, the above formula can be reduced to:

$\% S_{total} \times 10 =$ Tons $CaCO_3$ needed/Thousand tons of material. (2)

These calculations are based on analyses of minesoils indicating that on the average only one-third to one-half of the sulfur present is in a form that is likely to produce acid.

When fresh unweathered overburden material is evaluated for lime requirement some other properties of the material must be considered. Rock that is artificially pulverized for laboratory processing may not yet have released clay particles that will emerge upon weathering, and thus it may have a negligible buffering capacity, leading to a Woodruff Buffer lime requirement of zero. In this case the best estimate of lime needed is provided as illustrated in Section VII, Acid-Base Accounts, or on a practical basis the use of equation (1) above.

PARTICLE SIZE DISTRIBUTION AND MINERALOGICAL PROPERTIES OF SELECTED OVERBURDEN MATERIAL

It is well known that amount and type of clay minerals present in the overburden material play an important role in determining the suitability of the material for physical stability and plant growth. It is also known that a knowledge of the clay minerals plays an important role in understanding weathering and soil forming processes. Therefore it is important to have clay mineral analyses as an integral part of any overburden characterization program.

Several locations included in a previous study (West Virginia University, 1971a) were further studied in this work. Samples taken from Sites Q, HH, A-A', 17, B-B', 1, O, and NN (Appendix E, and Section IV) were analyzed for particle size distribution and also for mineralogy which is still progressing. Samples from location Q and HH have been processed for mineralogical analyses, which were carried out on the less than two micron clay fraction. Oriented mounts of the potassium and magnesium saturated clay for X-ray diffraction analyses were made by drying a clay suspension on to a glass slide. Magnesium saturated clay was also glycerol saturated before preparation of the glass slides. Diffraction analyses were made of the Mg-saturated samples after air drying at room temperature and also after heating the glass slides at 110°C. The K-saturated samples were analyzed after air drying and after heating to 110°C, 350°C, and 550°C. A semi-quantitative estimate of the different clay minerals in a sample was made from relative peak intensities. Diffractograms were made with a Siemens Crystalloflex IV, X-ray diffractometer, using nickel-filtered copper radiation and a scintillation detector.

Particle size distribution (Mechanical Analysis)

Table 49 shows results of mechanical analyses of coal overburden material obtained from six locations. Samples from weathered zones of locations Q, HH, A-A' 17, O, and NN are somewhat similar so that one can assume that methods to establish cover crops and prevent erosion would be similar, strictly from a particle size distribution point of view. All samples from these locations contain much greater percentages of silt and clay compared to sand. The sand fraction seldom exceeded 20% of the total. Presence of large amounts of clay should provide high buffering capacity to control acid runoff and prevent loss of applied nutrients due to leaching or surface runoff. It is important to point out that the presence of large amounts of silt in the overburden material may create soil erosion problems if the spoil is not properly graded and planted to vegetation.

Samples taken from unweathered zones generally contain higher amounts of sand and lesser amounts of clay. This indicates that most of the clay minerals present in this overburden material are present in the coarse fractions. Weathering of this material will result in the production of a greater amount of clay.

Table 49

Distribution of Sand, Silt and Clay in coal overburden material from several locations where clay mineralogy has been determined.

Sample Site	Depth (ft)	Coal	Sand (%)	Silt (%)	Clay (%)
Q	10-13'	Bakerstown	18.30	29.40	52.30
Q	23-38'	Bakerstown	8.76	64.14	27.10
Q	40-52'	Bakerstown	6.04	59.14	34.78
HH	0.2-0.5'	Redstone	12.68	65.90	21.42
HH	2-4'	Redstone	4.68	49.70	45.52
HH	14-16'	Redstone	22.84	51.64	25.52
HH	27-28'	Redstone	20.28	61.06	18.66
HH	47-48'	Redstone	8.10	70.26	21.64
HH	57-58'	Redstone	6.48	70.44	23.08
A-A', 17b	12-13'	Pittsburgh	54.48	35.38	10.14
A-A', 17a	20-22'	Pittsburgh	1.12	76.60	22.28
A-A', 17a	40-42'	Pittsburgh	30.52	45.90	23.58
B-B', 1a	44-45'	Lower Kittanning	16.20	60.04	23.76
B-B', 1a	66-67	Lower Kittanning	15.62	61.16	23.22
O	0.5-2'	Lower Kittanning	17.76	52.22	32.02
O	12-14'	Lower Kittanning	46.22	31.38	22.40
O	34-36	Lower Kittanning	36.84	39.94	23.22
O	45-46'	Lower Kittanning	22.08	57.94	20.08
O	59-60'	Lower Kittanning	30.68	52.86	16.48
O	76-77'	Lower Kittanning	22.48	45.68	31.84
NN-b	8-9'	Sewell	18.04	53.58	28.38
NN-b	25-26'	Sewell	15.14	58.28	26.58
NN-b	47-48'	Sewell	34.06	48.56	17.38

Mineralogical analysis

The mineralogical data of samples taken from locations Q and HH are given in Table 50. All samples from Site HH contained mixtures of kaolinite, mica, vermiculite, and quartz. A sample taken from a depth of 14 to 16 feet at Site Q also revealed the presence of calcite. Kaolinite was the dominant clay mineral present at all depths. There was a greater amount of vermiculite (non-collapsible) in the soil zone (3" to 5" depth) and less mica. As the depth increased at this location, the amount of mica also increased. Decrease in the amount of vermiculite and increase in the amount of mica with depth indicates that most of this vermiculite may have formed from alteration of mica during weathering of rock material. Such a relationship was also reported previously at a different location (West Virginia University, 1971a). Presence of calcite at lower depths (in the unweathered zone) and its absence in the weathered zone further indicates acid weathering of this rock material before its exposure to the atmosphere. The non-collapsible nature of the vermiculite in the soil zone indicates that in the upper zone where weathering is more intensive, aluminum may have accumulated in inter-layer positions of this clay and as a result prevented collapsing of vermiculite. These results indicate that aluminum produced due to weathering may be readily fixed by vermiculite and, as a result, toxic effects of this cation on plant roots may be reduced under acid conditions.

At Site Q, mica is the principal clay mineral in the upper zone and kaolinite is a dominant mineral in the deeper zone. Vermiculite was present only in the sample taken from the 40 to 52 foot depth. Absence of vermiculite in the upper zone and its presence at lower depth is a good indication of the variability in the dominantly calcareous mudrock. The presence of higher proportions of mica in this material indicates a good potential to supply potassium to plants. Weathering of mica will also result in the formation of vermiculite.

The mixed mineralogy of these materials should not pose any difficult problems in establishment and growth of crops. Clay mineralogy of Sites Q and HH is of special interest because the calcareous mudrocks involved are being considered for use as topsoiling materials on nearby acid sandstone minesoils and minewastes, and also because rocks at HH are considered relatively sensitive to slippage on steep slopes. It is apparent from the data that a tendency to slip downhill on steep slopes does not require presence of montmorillonite. In fact, the weak cohesiveness of kaolinite and disseminated calcite may contribute to observed instability.

TABLE 50

Clay mineral composition, from X-ray diffraction analysis, overburden material overlying the Bakerstown (Site Q) and Redstone (Site HH) coal seams. Quartz: p = present, a = absent; Layer Silicates, only: -- = absent, 1 = trace, 2 = low, 3 = medium, and 4 = high (up to 50% of total fines); ** = Non-collapsible vermiculite (aluminum-interlayered)

Location	Depth	Kaolinite	Mica	Calcite	Vermiculite	Chlorite	Montmorillonite	Quartz
Site Q	10-13'	2	4	--	--	--	--	p
Site Q	23-38'	2	3	--	--	--	--	p
Site Q	40-52'	4	2	--	2	--	--	p
Site HH	3-5"	4	1	--	2**	--	--	p
Site HH	2-4'	4	2	--	2	--	--	p
Site HH	14-16'	4	2	2	2	--	--	p

SECTION IX

PETROGRAPHIC INVESTIGATION OF SANDSTONE WEATHERING

Observations of many sandstone overburdens and sandstone-derived minesoils made throughout our studies indicate that large differences in friability, resistance to mechanical breakdown, and weathering in a minesoil occur among the various sand members of the geologic section. Recognition of overburden materials that are physically stable will allow better construction of French drains and outslope foundations, whereas readily weatherable rocks make better soils. Properties of coal overburden and resulting minesoils that require greater attention than in the past are rate of breakdown of large fragments and capacity to retain water for plant growth and prevention of excess drainage or runoff. Detailed investigation of some of these physical properties of overburdens, principally sandstones, are reported in this Section.

WEATHERING OF SANDSTONE

In order to better understand the weathering of overburden sandstones, exposures representing different lithologies and subjected to different degrees of weathering were studied. These included natural outcrops and old and recent exposures in road cuts and surface mines. Most of the localities were in northern West Virginia but a few were in central West Virginia and Ohio. Critical samples were thin-sectioned and studied under the petrographic microscope. The clays in a few specimens were X-rayed.

GENERAL PETROLOGY OF SANDSTONES

Sandstones are composed of a framework of grains with the space between the grains being partly or completely filled with an argillaceous matrix or a chemically precipitated cement. The framework grains range in size from 1/16 mm to 2 mm. The grains are most commonly monocrystalline with quartz predominating and smaller amounts of potash feldspar, sodic plagioclase, muscovite, biotite, chlorite and minor accessory minerals. Some grains are polycrystalline representing fragments of such rocks as quartzite, chert, shale, slate, phyllite and schist.

The framework grains are held together by a precipitated cement, argillaceous matrix material or derormed ductile grains. The most common precipitated cement in the Pennsylvanian sandstones is quartz. The original quartz grains in the framework act as seed crystals on which secondary quartz grows in a crystallographically continuous manner. Generally the initiation of overgrowth is so perfect that the boundary between the original grain and the overgrowth can not be determined. Well-formed crystal faces develop where quartz grows freely into pores without obstructions. Less commonly calcite or dolomite act as a cementing material in some pores (Figure 18). Carbonates also replace such framework grains as feldspar and mica. This carbonate does not increase the strength of the sandstone and with later leaching might be a factor leading to the breakdown of the rock.

The argillaceous matrix may originate in several ways. In part it represents an original "mud" deposited with the sand-size grains. Later recrystallization of this material would presumably lead to interlocking of the argillaceous particles resulting in an increase in the coherence of the matrix and hence a more strongly bonded sandstone. Some pores may be filled with products resulting from the alteration of unstable framework grains such as feldspar (Figure 19). Part of the argillaceous material may be introduced after deposition. The chief matrix minerals are illite, sericite, kaolinite and chlorite. Some of these same minerals may occur as constitutents of framework grains either as original components or as alteration products of primary minerals such as feldspar or mica (Figure 20).

Compaction of sandstone reduces the pore space between the framework grains and normally increases the strength of the sandstone. Where an original argillaceous matrix is present, the compaction increases the coherence of the matrix and hence its ability to hold the framework grains together. Compaction causes ductile grains composed of mica, shale, slate, phyllite or schist to deform in such a way that they tend to wrap around rigid grains and are squeezed into pore spaces. This deformation commonly results in the ductile grains acting as "keystones" and playing an important role in increasing the coherence of the sandstone. Deformed ductile grains which are composed of fine-grained minerals tend to blend into the matrix so that they are difficult to distinguish from the original matrix in some cases. Not all the argillaceous material is well compacted. Some of the kaolinite developed in the pores after compaction and forms a loose mosaic which is not effective in bonding grains together.

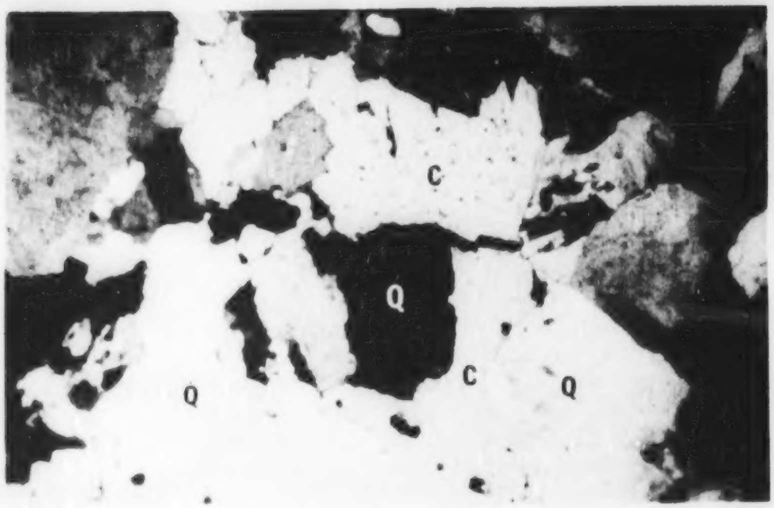


Figure 18. Microphotograph showing carbonate acting as an effective cementing agent in a calcareous sandstone. Q=Quartz, C=Carbonate Buffalo Sandstone, Site 20. Crossed Nicols, x55

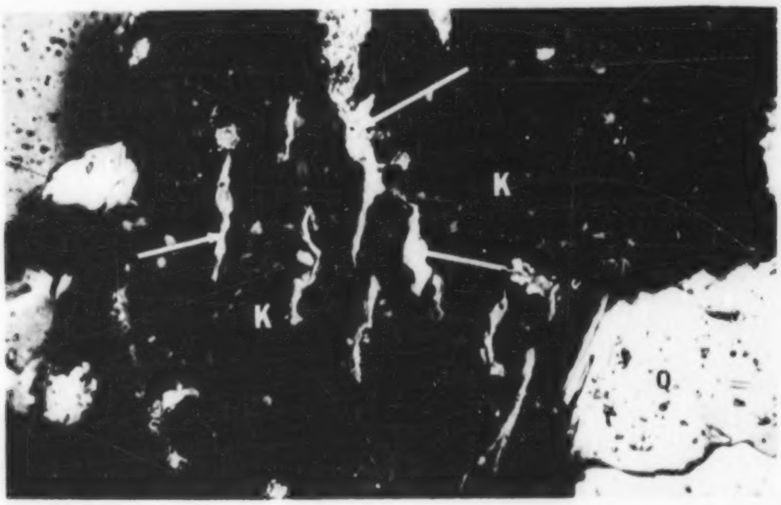


Figure 19. Microphotograph showing kaolinite replacing feldspar. Remnants of feldspar (arrows) are visible surrounded by kaolinite with its characteristic mosaic appearance. Q=Quartz, K=Kaolinite Buffalo Sandstone, Site 20. Crossed Nicols, x 200

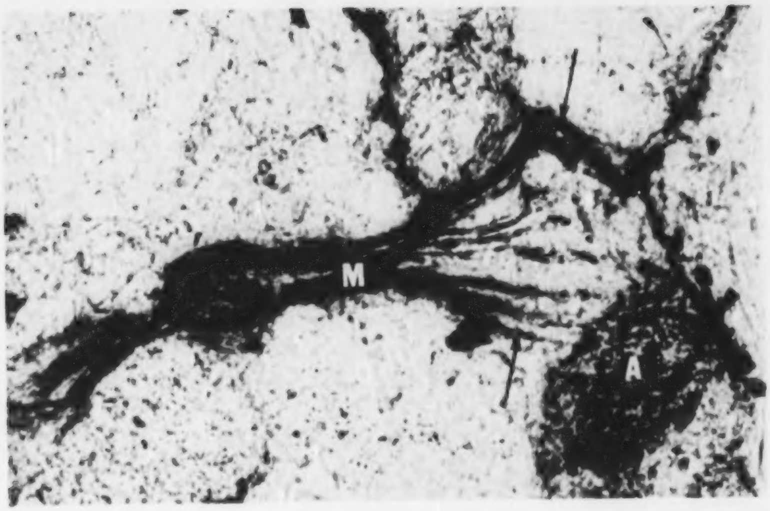


Figure 20. Microphotograph showing a mica flake flared (arrows) at one end by invading argillaceous material. Iron oxide outlines the original cleavage planes of the mica. Sandstone with mica between grains and those with the mica concentrated along bedding planes are generally weak and break down readily. Q=Quartz, M=Mica, A=Argillaceous material (Black areas are iron oxide stain)
Allegheny Formation, Site 14, Plain light, x 200

Quartz grains undergo pressure solution where grains are stressed at contacts as a result of the weight of overlying rocks. This may lead to considerable compaction of the sandstones. Pressure solution produces highly sutured contacts between grains in some cases and this interfingering increases the cohesiveness of the sandstone. Illite or sericite between grains tends to accelerate the pressure solution process. Stylolite seams are another manifestation of pressure solution. If the seams are not highly sutured, they may act as zones of weakness because of the additional argillaceous material that accumulates as a residue of solution along the seams.

Unweathered sandstones differ considerably in coherence because of these differences in original lithologies, cementation and compaction. The degree of weakening from weathering depends on the original characteristics of the sandstones and on the intensity of weathering. With all these different factors, it is not surprising that the rate of breakdown of sandstones is so variable.

PETROGRAPHY OF SANDSTONES AT SELECTED SITES

Pottsville Series

The Connoquenessing Sandstone was studied at the new roadcuts of Corridor E near the entrance to Coopers Rock State Forest (Appendix F, Sites 1, 2). The Connoquenessing at this locality is a fairly massive, resistant, medium to coarse grained, clean, quartz sandstone with widely spaced parallel joints. The sandstone is characteristically gray on the surface but light brown from iron staining in the interior. Well-developed secondary quartz faces tend to give the rock a sparkling appearance. Some of the float blocks which had been broken into smaller boulders during road construction were much more friable than the surrounding rock. Blasting may have effectively loosened the grains leading to the observed weakness in the rock. It is possible that these blocks had not been well indurated, but this seems unlikely because friable sandstone is not present in the undisturbed rock. In any case there are potential sources of at least small quantities of sand forming material even in this area of relatively resistant rock.

Thin section study indicated a quartz content of 83 to 90 percent (Table 50, # 1, 2, 3). Porosity ranged from 4 to 13 percent. Small masses of argillaceous material were present in some interstices but the quantity was so small ($< 5\%$) that it probably did not have a significant effect in bonding the rock. Secondary quartz faces were abundant where available pores were present to allow uninhibited growth. These secondary growths also provided an interlocking of grains for added

Table 51. COMPOSITION OF SANDSTONES INCLUDED IN PETROGRAPHIC STUDY OF SANDSTONE WEATHERING
(percent by volume including pore space)

Sample Number	Quartz	Chert Grains	Feld-spar	Coarse Mica	Identifiable Kaolinite	Other Argillaceous Material	Carbonate	Pyrite	Iron Oxide	Miscellaneous	Porosity
1	83				1	2[a]			1		13[b]
2	84			tr	3	1			1		10
3	90			tr	1	2		tr	2		4
4	83	tr			2	1			tr		13
5	82			tr	1	1					16
6	89				4	1					6
7	84			1	3	tr			tr		11
8	84		1	tr	2	6			1		5
9	87				1	1					10
10	87	tr		tr	2	2			tr		9
11	87	1		tr	6	5					1
12	89	tr		tr	3	1					6
13	58	1	5	3	tr	27	3		2	1	tr
14	60		4	2	tr	31			1	1	1
15	71	1	5	1	13	7					2
16	68	1		3	9	15		1	1		2
17	72	1	1	2	8	14	1	tr	tr		
18	84		1	tr	10	2	1	tr		1	
19	94				1	2			1		2
20	88			tr	3	3					6
21	74	tr		1	10	10		tr	tr		5
22	64	3		2	4	14	12	tr	tr	1	
23	64			2	7	18		tr			8
24	68	1	1	tr	2	23	1	tr	1	2	1
25	58	1	1	tr	3	18	15	tr	tr	3	tr
26	58		8	1	10	14			tr	3	5

[a] Includes fine-grained mica

[b] Porosity as observed in thin section. Locations where samples were obtained described in appendix F, page 297.

[c] Location and sites (detailed in appendix F) from which samples characterized in Table 50 were obtained.

Connoquenessing Sandstone
1-3. Corridor E near entrance to Coopers Rock State Forest. Sites 1 & 2.
4. Average of 2 samples. Deckers Creek Sand Co. quarry. Site 3.
5. From float at margin of quarry. Site 3.
6. Deckers Creek Sand Co. quarry at Site 4.
7. Deckers Creek Sand Co. quarry at Site 5.

Homewood Sandstone
8. Quarry 0.5 ml. north of Burns Chapel. Site 8.

Sandstone in Pottsville Series
9,10. Valley Falls State Park. Site 9.

Guyandot Sandstone
11,12. Surface mine west of Lobella. Sites 10 and 11.

Monitor Sandstone
13,14. Surface mine 2 mi. north of Summersville, Site 12.
13. Core of spheroid 14. Shell of spheroid.

Allegheny Sandstone
15. Road outcrop 10 mi. north of Summersville. Site 13.
16. Surface mine 3 mi. northeast of Brandonville. Site 14.

Buffalo Sandstone
17,18. Quarry across river from Uffington. Site 20.

Mahoning Sandstone
19. Surface mine 2 mi. northeast of Tunnelton. Site 15.
20. Road outcrop 2.5 mi. northeast of Tunnelton. Site 16.
21. Road outcrop 0.2 mi. east of Irona. Site 17.
22. Surface mine 2 mi. west of Masontown. Site 18.
23. Road outcrop 2 mi. south of Quiet Dell School. Site 19.

Sandstone in Conemaugh Series
24,25. Roadcut on 1-79 north of Fairmont. Site 22.

Sandstone in Monongahela Series
26. Surface mine 1 mi. northeast of Dexter City, Ohio. Site 27.

strength. Minor pressure solution was also apparent as evidenced by grain interpenetration and suturing. Iron oxide occurred in small amounts and in some cases acted as an effective cementing agent. Trace amounts of sphalerite occurred in one sample. The overall strength of the sandstone in this area is probably a result of interlocking of secondary quartz growths and suturing with some local cementation with iron oxide.

The Connoquenessing Sandstone was studied at the quarries of the Deckers Creek Sand Company 2 1/2 miles west of Masontown (Sites 3-5). Here the rock is a clean quartz sandstone exhibiting a sparkling appearance from secondary quartz faces. Grain size ranges from medium to coarse and color is generally white or light gray with some shades of brown locally. The sandstone in the quarry south of the road (Site 5) is moderately resistant and the quarry walls have remained essentially intact. In the active quarry north of the road (Site 3) much of the sandstone is highly friable and commonly disintegrates along the quarry walls (Figure 21). Float blocks at the margins of the quarry appeared to be much more resistant than the typical quarry rock but actually disintegrated easily when struck with a rock hammer. Apparently contaminants in the pores near the surface and lichen-type growths aided in keeping the surface of the boulders intact.

Thin section study of the sandstones indicated approximately 80-90 percent quartz, less than 5 percent argillaceous material and 6 to 16 percent porosity (Table 50, # 4-7). Secondary quartz growths exhibited well-developed faces. The argillaceous material was mainly kaolinite forming uncompacted mosaics in some of the interstices. Most of the quartz grains in the friable sandstones are separated by minute cracks but these are believed to have been induced in sample preparation for thin-sectioning.

The Homewood Sandstone was examined in two nearby sand quarries of the Deerfield Sand Company located on Route 119, 9 miles south of Morgantown (Site 6). The rock is a friable, massive, clean, quartz sandstone. Grain size ranges from medium to coarse and color is generally white although some of the sand is iron stained. The exterior weathered surface of this sandstone appears fairly resistant but in fact is quite friable and granulates readily. Thin section study of the sandstone revealed well-developed quartz faces. Relatively high porosity and lack of significant pressure solution effects indicated that the sediments had never been greatly compacted. Although secondary quartz growths are abundant, pores are only partially filled and grain interlocking has not reached the point of producing a coherent sandstone.

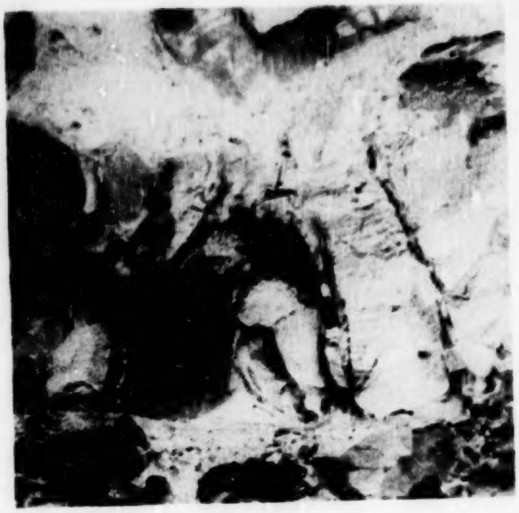


Figure 21. Deckers Creek Quarry - Typical face of the active quarry showing the extreme friability of the Connoquenessing Sandstone at this location. The weakness of the rock is evidenced by the general rounded appearance of the outcrop and accumulation of loose sand at the base of the quarry wall.
Connoquenessing Sandstone, Site 3

The Homewood Sandstone at the abandoned quarry one mile ESE of Summers School (Site 7) and the old Deckers Creek Sand Company quarry one-half mile north of Browns Chapel (Site 8) is also relatively friable. The sandstone forms fairly steep cliffs in some of the natural outcrops in the area but the corners of exposures tend to be rounded and the rock easily disintegrates with a hammer blow. It appears that much of the Homewood in this area never was well-lithified.

A sandstone in the Pottsville Series was studied at Valley Falls State Park south of Grafton (Site 9). In contrast to the Pottsville in the previously described sand quarries, this sandstone is very resistant. It is massive, fairly clean and porous. Grain size ranges from medium to very coarse and color is light to dark brown depending on the degree of oxidation. These rocks also exhibit the sparkling appearance resulting from reflection from secondary quarty faces. Thin section study of this sandstone revealed good porosity (10%) allowing uninhibited secondary quartz growth into the pores. The sandstone contained 86 percent quartz, less than 2 percent argillaceous material, 1 percent iron oxide, and a trace of chert grains. A few grains of slate were present, but constituted less than 1 percent of the rock (Table 50, # 9, 10). Apparently, the strength of this sandstone is a result of secondary quartz growth causing grain interlocking and minor suturing from pressure solution. Partial cementation by iron oxide may be a factor in the more resistant samples. The weaker samples seem to show less grain interlocking than the more resistant samples.

The Guyandot Sandstone was studied at a surface mine 5 miles west of Lobelia, Pocahontas Co. (Site 10). The sandstone overlies the Sewell Coal and is gray, medium grained, massive and very resistant. Thin section examination indicated a high quartz content with scattered argillaceous grains and metamorphic rock fragments (Table 50, # 11). Quartz was the main cementing agent with secondary growths filling pore spaces. Pressure solution along with quartz cement was very significant in effecting grain interlocking. This interlocking is apparently the main reason for the resistance of the sandstone.

The Monitor Sandstone overlying the Peerless Coal (Campbell Creek) was studied at a surface mine 2 miles north of Summersville on Route 19 (Site 12). Although the Monitor Sandstone is part of the Pottsville Series, it is much more argillaceous than the members of the Pottsville in northern West Virginia. The sandstone is massive, medium to coarse grained with wide variation in resistance to breakdown. Spheroidal weathering is particularly well developed in this area which accounts for most of the variation in rock resistance. This type of weathering is characterized by a spheroidal central core of resistant fresh rock surrounded by one or more altered concentric shells (Figure 22). The

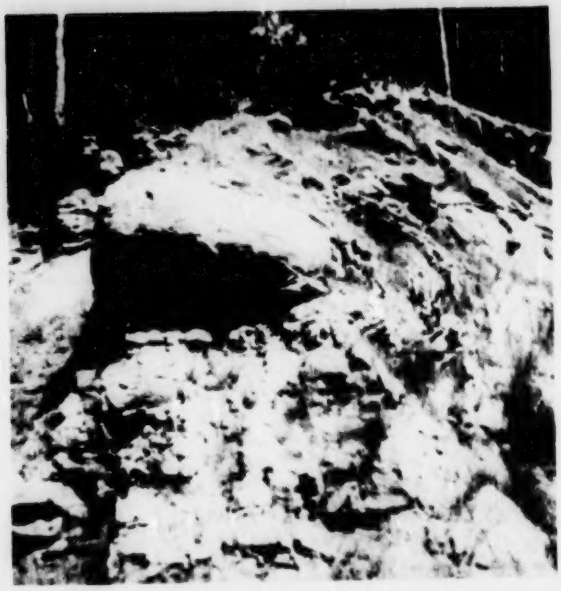


Figure 22. Core of spherodially weathered sandstone protruding from a surface mine highwall. The concentric outline of the highly altered shells can be seen surrounding the resistant core. The spheroidal weathering occurred before excavation but many of the shells disintegrated after exposure.
Monitor Sandstone (overlying Peerless Coal), Site 12

shells are generally a few centimeters thick but some are only a millimeter thick. Chemical alteration with expansion of the argillaceous material is the most likely cause of the spheroidal development. Spheroids in sandstones seem to form best where the rock is argillaceous, massive and vertically jointed such as is the case with the Monitor Sandstone in this area. Alteration begins along joint faces and extends to permeable bedding planes where water may move horizontally to the next vertical joint. When a joint block has been completely encircled, alteration may proceed along all faces of the block with the corners being attacked on three sides. As chemical alteration proceeds inward, concentric stresses are set up as a result of expanding argillaceous material. The rock splits to form a concentric shell when sufficient stress has built up to a point greater than the shearing strength of the rock. Alteration continues toward the center forming other shells until the complete spheroid has been altered. Some spheroids in the Monitor Sandstone of the Summersville area have been completely altered to the core whereas others have fresh gray cores surrounded by the less resistent altered concentric shells. The highly altered sandstone is so friable that it can easily be crumbled by hand.

Thin section study indicates that the sandstone is highly argillaceous and somewhat feldspathic. The argillaceous material is mainly fine micaceous material within grains of metamorphic rock such as slate and schist. The feldspar has undergone partial solution and alteration to kaolinite. The sandstone in some of the spheroidal cores has partially oxidized, iron-bearing carbonate which occurs in with the argillaceous material and feldspar. Some of the voids in the outer shell may have resulted from the dissolution of the carbonate and some of the feldspar. Microscopic study of one of the cores and successive shells revealed no obvious mineral change which would account for the expansion of the outer shells (Table 50, # 13, 14). However, alteration of argillaceous material probably occurred but was not detectable under the microscope. Preliminary X-ray examination indicates a possible increase in the amount of vermiculite in the outer shells.

Allegheny Formation

A sandstone in the Allegheny Formation was studied at a road cut on Route 19, 10 miles north of Summersville (Site 13). The sandstone is massive, medium to coarse grained, friable and argillaceous with iron-stained vertical joints. The extreme friability of the rock was indicated by its flaky appearance and lack of coherance when attempts were made to secure hand specimens. The outcrop exhibited a white appearance mainly because of abundance of white argillaceous material. Where joints dissected the sandstone, iron oxide was precipitated along the faces and in some cases extended to a depth of one meter into the rock.

The sandstone seemed to be more resistant along these faces apparently as a result of the iron oxide acting as a partial cementing agent. Thin section study indicated a high content of argillaceous material (Table 50, # 15). The extreme friability of this sandstone probably is a result of extensive alteration of the argillaceous material.

A thin resistant brown sandstone layer approximately two inches thick, occurred within the friable white sandstone. This layer was similar in lithology to the surrounding friable sandstone but apparently had been effectively cemented by iron oxide. In thin section, the iron oxide could be seen to completely surround most of the grains and to permeate the argillaceous material.

Conemaugh Series

The Buffalo and Mahoning Sandstones are lithologically quite similar. Excellent exposures of relatively fresh rock are to be found in the abandoned quarries of the Buffalo Sandstone in the Morgantown area. In addition to quartz and argillaceous material, the sandstone contains small amounts of feldspar, calcite and pyrite (Table 50, # 17, 18). Concretions and lenses of calcareous material, in some cases 2 meters across, occur locally. The calcite comprises 20 to 40 percent of these masses having replaced the argillaceous material and part of the feldspar and quartz.

Variations in weathering of the Mahoning sandstone were studied southwest of Kingwood. The Mahoning in this area varies from a friable to a very resistant sandstone. Color ranges from light brown to dark brown with some light gray sandstone.

One of the light gray sandstones was studied at a surface mine 2 miles northeast of Tunnelton (Site 15). The sandstone is fairly massive, very resistant and had a ringing sound when struck by a hammer. Thin section study revealed a fine to medium grained, fairly clean, quartz sandstone containing small patches of argillaceous material. It was composed of approximately 94 percent quartz, 4 percent argillaceous material, and 0.5 percent iron oxide (Table 50, # 19). Pressure solution was evidenced by suturing resulting from grain to grain interpenetration. The strength of this rock is apparently the result of suturing from pressure solution and secondary quartz growth resulting in firm grain interlocking.

The brown oxidized sandstones of the Mahoning varied considerably in their resistance to breakdown. These sandstones were studied at a surface mine 2 1/2 miles northeast of Tunnelton (Site 16) and at an abandoned quarry and road cuts near Irona (Site 17). Thin section study revealed a medium-to-coarse-grained sandstone varying from 70 to 90 percent quartz, less than 1 percent coarse mica, 6 to 20 percent argillaceous material and less than 6 percent porosity (Table 50, # 20, 21). A moderate amount of pressure solution had occurred and there was some evidence of secondary quartz growth. In samples where iron oxide surrounded individual grains, the rock was fairly resistant. In the weaker sandstones the iron oxide was more concentrated in separate clots. Alteration of argillaceous material undoubtedly contributed to the weakness of many of these rocks.

The Mahoning Sandstone was also studied at an abandoned surface mine two miles west of Masontown (Site 18). The rocks range from resistant to friable sandstones. The typical rock is a fairly massive, medium grained, argillaceous, micaceous sandstone. Outcrop samples weathered under oxidizing conditions exhibited a brown to pinkish color. Some boulders which were broken from the high wall had a protective coating of iron oxide on one or more of its sides. These boulders had apparently been detached along joints where circulating waters deposited iron oxide along the joint faces. Boulders exposed with the coating on top remained intact whereas boulders of the same lithology with no iron oxide coating broke down readily. Once this protective coating is removed, breakdown proceeds normally. Many of the dark gray rocks have micaceous partings and break down quite readily if left exposed with the parting planes vertical. The pinkish brown rock exhibits variable resistance. Some blocks of this sandstone are fairly resistant whereas others completely disintegrate in a relatively short time. Differences in extent of pre-excavation alteration probably account for these differences in resistance.

Thin section study indicated that these sandstones are argillaceous and of low porosity. Some of the argillaceous material is in grains of metamorphic rock such as slate, phyllite and schist. As a result of compaction these relatively ductile grains are molded around more rigid grains and have been squeezed into some of the original interstitial pores. Kaolinite is conspicuous in some of the sandstone both as a pseudomorph after framework grains such as feldspar and as an interstitial pore filling. The kaolinite is conspicuous in hand specimens as white powdery clots. One sample contained moderate amounts of iron-bearing carbonate and small amounts of pyrite (Table 50, # 22). The carbonate was conspicuously stained from partial oxidation of iron but the pyrite was relatively fresh. Voids at the margins of some of the carbonate were a result of leaching.

Most of the variability in resistance of these rocks is probably due to differences in degree of alteration of argillaceous material. Breakdown of the rock with mica concentration along bedding planes is apparently caused by expansion of the micaceous material as alteration proceeds inward from the margins. The micaceous layer may also have prevented quartz from growing across the bedding planes and interlocking the beds.

The most friable Mahoning sandstone studied is exposed 2 miles south of the Quiet Dell School (Site 19). The sandstone in this area is argillaceous and reddish brown. Mica gives the rock a glistening appearance from surface reflections from the mica flakes rather than from well-developed quartz faces as is characteristic of many of the clean Pottsville sandstones. Thin section study revealed fine to medium grain size with an abundance of mica flakes and argillaceous material. Mineral composition was approximately 64 percent quartz, 2 percent coarse mica, 25 percent argillaceous material, 2 percent iron oxide and a porosity of 8 percent (Table 50, # 23). In all sections studied, iron oxide was present and undoubtedly imparted the conspicuous reddish brown color to the sandstone. The iron oxide had surrounded most of the grains and infiltrated much of the argillaceous material. The extreme friability of this sandstone apparently resulted from a high degree of alteration of the abundant argillaceous material. Some of the voids appear to be the result of dissolution of carbonate and perhaps some feldspar.

Sandstones of the Conemaugh Series were studied along Interstate 79 between Fairmont and Morgantown. Most of the sandstones were relatively fresh and resistant (Sites 21-25). However, at a road cut one half mile north of the Pleasant Valley exit (Site 24), one of the sandstone beds had undergone spheroidal weathering before being exposed in the highway construction. The shells were very friable and in some cases the weakening from weathering extended through the cores.

At many of the road cuts blasting lead to disintegration of some beds near blast holes whereas other beds along the same hole remained resistant. In the road cut one mile north of the Downtown Fairmont exit (Site 22) the sandstone was sampled to determine why different beds responded differently to blasting. The sandstone beds were gray and resistant outside of the blast zone (Table 50, # 24). However, near the balst hole some beds were very friable. In thin section the friable sample exhibited conspicuous cracks around many grains and some of the grains themselves were fractured. This pervasive fracturing was the cause of weakness leading to rapid disintegration. A thin bed of calcareous sandstone (Table 50, # 25) extending into the same blasted zone showed no friable tendencies. No cracks were observed in thin section indicating that the strong bonding from the carbonate cement prevented separation of the grains. These samples show that blasting will lead to disintegration of sandstones which have some potential weakness but will cause only normal fragmentation of strong resistant beds.

A Conemaugh sandstone was studied south of Grafton at the intersection of Routes 119 and 250 where recent highway construction has resulted in new exposures (Site 26). The sandstone is fairly massive, slightly calcareous and medium grained. Chlorite imparts a greenish color to the sandstone. Spheroidal weathering is apparent not only in the older outcrops but also in the newly exposed areas. These spheroids range in size from approximately one-half to 2 meters in diameter. The cores are greenish gray and slightly calcareous. The concentric shells are light to dark brown from oxidation of iron and are non-calcareous. The shells do not granulate easily but they fragment into small blocks fairly readily. Older spheroids which have been exposed along the road for many years are dark brown and exhibit polygonal tension cracks on their surfaces apparently from continual expansion of argillaceous material in the inner layers. Iron oxide has been precipitated along the inner surfaces of most of these older concentric shells.

Monongahela Series

Many of the sandstones overlying coal in eastern Ohio are especially friable. One of the sandstones in the Monongahela Series was studied at a surface mine one mile northeast of Dexter City, Ohio (Site 27). The sandstone is light gray, moderately argillaceous and porous (Table 50, # 26). The coherence of the sandstone shows considerable variation apparently from differences in degree of original lithification as well as in extent of alteration of argillaceous material which occurred before removal of overburden. On a given spoil bank, some of the excavated blocks of sandstone have completely disintegrated; whereas others are still intact (Figure 23). All the blocks were subjected to the same weathering conditions for the same length of time on the bank. These variations in disintegration are a reflection of the differences in the coherence of the sandstone which existed before excavation.

WEATHERING CHARACTERISTICS OF DIFFERENT SANDSTONE TYPES

The rate of breakdown of sandstones mainly depends on original lithology and the extent and nature of weathering before excavation. In considering weathering behavior, the sandstones may be divided into 3 general groups: Argillaceous Sandstones, Calcareous Sandstones, and Clean Sandstones.

Argillaceous Sandstones

Most of the argillaceous sandstones studied were originally well lithified. Bonding by argillaceous material is the main factor in coherence. The argillaceous material is chiefly illite, sericite, kaolinite and chlorite. Some of this material was an original matrix which compacted and probably recrystallized. Ductile grains of mica, shale, slate, phyllite and schist which have been squeezed into pores aid in binding the other framework

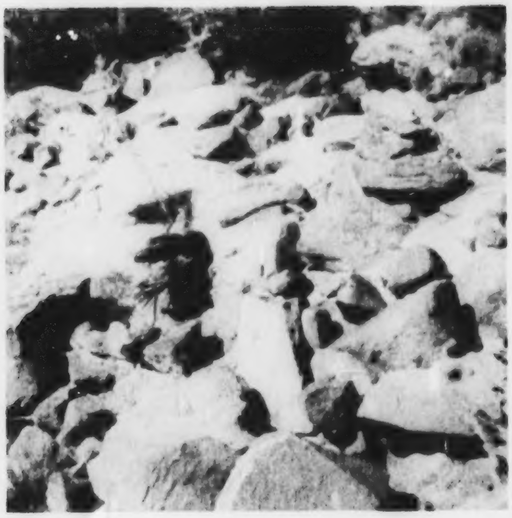


Figure 23. Sandstone boulders on an old spoil bank exhibiting variation in resistance to weathering. Many of the weaker sandstones granulate readily whereas those which are more resistant remain fairly angular.
Sandstone in Monongahela Series, Site 27

grains together. Quartz and calcite cement normally play a minor role in the bonding of these rocks. Locally sutured contacts resulting from pressure solution tend to increase the coherence of the sandstone.

The unaltered argillaceous sandstones are generally slow to weather. This is shown by the durability of rock in old stone buildings and the presently observed resistance of the sandstone in many old road cuts. However, prolonged alteration before excavation commonly results in a very friable rock. The alteration is basically a weathering phenomenon but extends to a depth of 8 meters in some places. The alteration may occur under oxidizing conditions producing shades of brown or under reducing conditions leaving a gray sandstone which on casual inspection resembles a "fresh" unaltered sandstone. Thus the argillaceous sandstones vary considerably in their rate of breakdown ranging from highly resistant to very friable depending mainly on the extent of pre-excavation alteration.

Special problems are encountered in the study of highly friable rocks. Sampling is difficult because the rock is so fragile that it crumbles easily. Although the specimens were thoroughly impregnated before thin-sectioning, some of them showed cracks between grains that appeared to have been recently induced (Figure 24). Natural fractures commonly have iron oxide staining but the general cracks in the friable sandstones are free of impurities. Apparently the specimens were so weak that jarring during collecting and preparing for impregnating induced the cracks. Porosity due to the opening up of the cracks normally amounted to 2 or 3 percent and was not included in the figures for porosity in Table 50.

The petrographic differences between the resistant rock and the altered friable rock are very subtle. In thin section, resistant rock and altered rock from the same bed show no obvious differences in variety of minerals or relative abundances. The altered rock is more commonly stained brown by oxidation of iron-bearing minerals but the oxidation in itself did not necessarily have a weakening effect. In fact, some of the iron oxide acted as a binder and produced a fairly resistant rock. Some of the argillaceous sandstones originally contained small amounts of carbonate which was leached on alteration. However, the carbonate content of most of these rocks was so low that its removal was not a significant factor in the breakdown of the rock.

A subtle change in the argillaceous material must be the cause of the weakness in these sandstones. Some sandstones even with "non-expandable" clay minerals undergo expansion and contraction with wetting and drying (Roper and others, 1964). These volume changes occurring over long periods of time might have been a factor in weakening the bonds in the Pennsylvanian sandstones. Preliminary X-ray work has indicated that

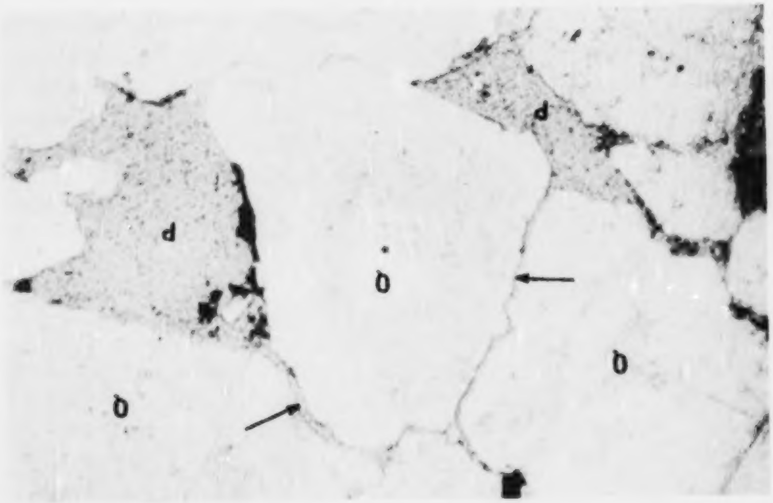


Figure 24. Microphotograph showing minute crack (arrows) between grains. Outline of individual grains adjacent to cracks seem to match, indicating that the grains had at one time been in contact. These cracks are limited to the friable sandstone and were apparently induced in preparing the sample for thin sectioning. Q=Quartz, P=Pore Space (Black Material is iron oxide) Connoquenessing Sandstone, Site 5. Plain light, x 70

vermiculite may have developed to a greater extent in the more friable rocks. If new clay minerals are forming, they might act as poorer bonding agents than the original argillaceous material which had become compacted. Furthermore, expansion attending development of late clay minerals might have had a disruptive effect. More quantitative studies on the proportions of the various clay minerals might lead to a better understanding of the factors causing the breakdown of argillaceous rocks.

In general, the higher the argillaceous content, the more likely the rock is to be friable on alteration. However, moderate amounts of argillaceous material critically distributed between framework grains may lead to a very friable rock. For instance, small amounts of clay rimming grains may alter and lead to complete breakdown of the sandstone. Even framework grains of quartzite with small amounts of mica are weak in some sandstones, apparently from alteration of the micaeous material.

The altered argillaceous sandstones exhibit various degrees of friability at the time of excavation with some coherent enough to yield boulders. However, when these boulders are left on the surface they completely disintegrate in a few years. Some of the boulders are laced with small cracks forming polygonal patterns which presumably are the result of shrinkage. Apparently wetting and drying of the altered argillaceous material causes expansion and concentration which leads to the breakdown of these sandstone boulders.

Some sandstones undergo spheroidal weathering in which onion-like shells form on the outside while the interior core remains intact. The units range from half a meter to 4 meters across. Spheroidal weathering best develops in argillaceous sandstones which are vertically jointed and free of closely spaced horizontal partings. Waters circulating along the joints and bedding planes apparently promoted alteration of the sandstone. Expansion attending this alteration causes shells to split away from the less altered core portion. Alteration was then probably facilitated by the greater circulation along the openings between shells. The component which expanded was presumably the argillaceous material. In the samples studied, alteration of feldspar was not a factor because the feldspar in the outer shells had not undergone any more change than that in the core. The shells in some rocks are very weak and granulate readily; whereas other rocks have stronger shells which fragment into blocks.

Spheroidal weathering is particularly well-developed in the sandstones in the Summersville area of West Virginia and commonly extends to a depth of 8 meters below the surface. Some of the outer shells are so highly altered that they completely disintegrate on excavation. Inner shells are stronger but fragment into blocks which disintegrate fairly readily. More advanced weathering nearer the surface altered even the inner cores in some places so that the complete rock crumbles readily. The areas of spheroidally weathered sandstone are potential sources of considerable sand for soil with proper reclamation planning.

Argillaceous sandstone with closely spaced micaceous layers along bedding planes weather rapidly. There are two main reasons for the breakdown. The layer of argillaceous material effectively prevents quartz from growing across the bedding planes; thus strong interlocking between the beds does not occur. Furthermore, expansion of argillaceous material along the bedding planes causes a splitting into thin sheets which then readily disintegrate. Alteration proceeds inward from the margins so that there is a strong wedging effect as the outer portions expand. Blocks which are situated with the bedding vertical deteriorate most rapidly. This type differs from most other argillaceous sandstones in that it will break down readily without previous alteration before excavation. Of course, disintegration is even more rapid if some pre-excavation alteration has occurred.

Calcareous Sandstone

A sandstone cemented with carbonate will breakdown rapidly as the carbonate is dissolved under weathering conditions. If the carbonate forms up to about 20 percent of the framework of a quartz cemented sandstone, voids will develop on weathering, but the rock normally will remain intact. In very highly calcareous sandstones, waters effecting weathering become readily neutralized so that these sandstones do not breakdown as rapidly as some of the less calcareous types.

Clean Sandstones

The clean sandstones are composed mainly of monocrystalline quartz with some grains of chert and quartzite. Feldspar, mica and grains of argillaceous rocks are scarce. An original argillaceous matrix is lacking. Uncompacted kaolinite occurs in some pores and probably is of post-deposition origin.

Even in clean quartz sandstones there is great variation in bonding; yet the factors controlling these variations are commonly difficult to ascertain. It is apparent that a sandstone with practically no cement will be very weak and one which is completely cemented under favorable conditions with elimination of all porosity will be very resistant to breakdown. Some of the sandstones of Pennsylvanian age fall into these categories and their behavior under weathering conditions can be predicted with certainty. However, many of the clean sandstones fall between these two categories and the reasons for differences in rate of breakdown are not readily apparent. One might expect friability to increase with porosity but the relationship is not simple. Some low porosity sands are friable whereas others with considerable porosity are strong. Low porosity in friable sandstones might have resulted from compaction facilitated by pressure solution without development of quartz cement. If deep suturing did not occur, grains would separate quite readily. On the other hand, quartz cement in the form of overgrowths could lead to an interlocking of grains which would resist separation even where some porosity remains (Figure 25). It is possible that later pressure solution might destroy some of the interlocking thus leading to a friable sand in spite of the quartz cement.

Some workers believe that the friability of pure quartz sandstone is due to a weakening of the rock through solution of quartz. For example, Fettke (1918) in his classic study of the Oriskany glass sands, emphasized the solution of quartz in promoting friability. However, careful microscopic study shows no evidence that quartz has dissolved. Quartz faces sparkle and lack any traces of frosting or etching. Some of the faces are minute facets and even these have sharp edges. The faces are best developed in pores and along joints where they are most exposed to circulating waters. When cracks are seen between grains in thin sections, it is apparent that they have mechanically separated for the sides are generally irregular; yet it is clear that the two sides would mesh together perfectly. For every projection on one side, there is a corresponding re-entrant on the other side.

It appears that the tightness of the bonding at time of excavation will determine the rate of breakdown of the clean sandstones rather than chemical weathering. Although some of the weakly bonded sandstones appear superficially to be similar to resistant sandstones, they break down quite easily with relatively mild blows with a geologic hammer. The nature of the outcrop also furnishes an important clue as to the resistance of the sandstone. The poorly bonded types have rounded edges rather than the angular shapes of the resistant sandstones. The erroneous conclusion is easily drawn that a sandstone found in large boulders is necessarily resistant. Some blocks of the Pottsville sandstone are at least as large as small houses; yet may be composed of relatively weak sandstone. Joints in the Pottsville are commonly widely spaced so that huge boulders develop in the normal processes of mass-wasting. Even with reduction in size through disintegration at the margins, these boulders will be of above average size for a long time.

Rounded surfaces near the base of a cliff or along some joints are not consistently an indication of rock weakness. The rounding may be a result of spalling from efflorescence. The efflorescence is greatest on surfaces sheltered from heavy rainfall and where sulphate bearing waters

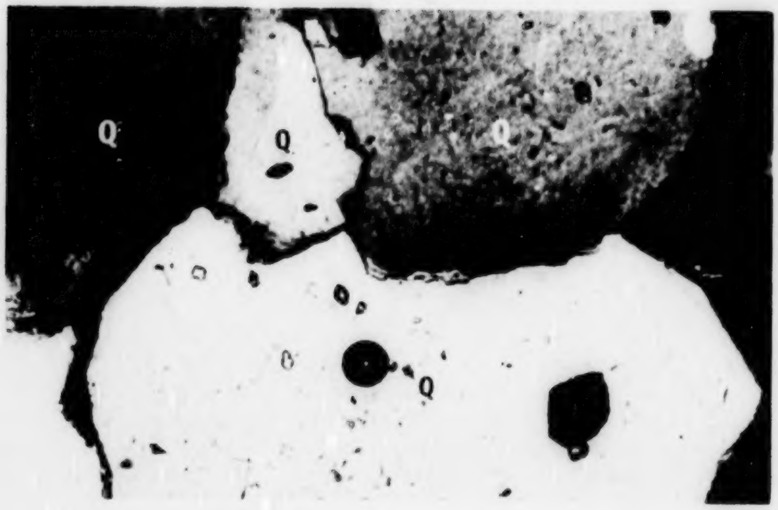


Figure 25. Microphotograph showing grain interlocking, caused by growth of secondary quartz. Grain interlocking in the clean quartz sandstones is apparently the main factor controlling the strength of the rock.
Q=Quartz Homewood Sandstone, Site 6. Corssed Nicols, x 200

are flowing toward the surface. Commonly the effects of efflorescence are greatest in the weak sandstones; however, in some sandstones the friability is limited to the areas of efflorescences and the remainder of the rock is very durable.

APPLICATIONS

A knowledge of the weathering characteristics of sandstone is of practical value in making the best use of excavated material. Moderately calcareous sandstones are hard at the time of excavation but fragments will break down relatively rapidly where left near the surface so that circulating waters are able to remove the carbonate. Sandstones with micaceous partings may also be hard at the time of excavation but will disintegrate readily near the surface.

Most of the argillaceous sandstones that break down readily are tan or brown for the obvious reason that they have been oxidized during weathering near the surface. The argillaceous sandstones that have altered under reducing conditions are deceiving in that they are gray and by casual inspection resemble fresh rock which would be resistant to breakdown. However, some of these sandstones are among the fastest to disintegrate. They usually can be recognized by the presence of soft clay in the interstices and a noticeable lack of brittleness when struck by a hammer. Generally the most altered argillaceous sandstones are near the original land surface where they have been permeated by more reactive waters. However, some beds at moderate depths are more friable than some of the overlying beds because the deeper beds happened to be more susceptible to alteration on account of composition or permeability. For this reason, a possible source of friable sand at intermediate depth should not necessarily be ruled out simply because a shallow resistant bed has been encountered.

The altered argillaceous sandstones are particularly useful where additional sand would be beneficial in the soil. In spheroidally weathered sandstone, both resistant and friable sandstone is available. The material in the outer shells is weak and is a potential source of sand size material. The hard cores are resistant to disintegration and could be utilized as fill where stable conditions are required.

In the clean quartz sandstones the degree of friability is extremely variable because of differences in bonding. However, these variations in strength are ordinarily apparent at the time of excavation. The weakly bonded types which will disintegrate readily crumble with light hammer blows even in fresh appearing specimens. On the other hand, the clean sandstones which are strong when excavated will remain essentially intact in spite of severe weathering conditions.

Some sandstones are greatly weakened by shock near blast holes. Partings occur along concentric cylinders approximately parallel to the blast holes. In some cases the shattered zone is as much as one meter in diameter. Weathering is greatly facilitated by the presence of the partings and disintegration is relatively rapid. The strongest sandstones are not shattered by blasting but sandstones which show only slight signs of weakness may become vary friable around the blast hole. Outside of the blast zone the sandstone is coherent and weathers very slowly. Blasting techniques probably could be adjusted to increase the amount of disintegrated material where additional sand in the soil would be beneficial. On the other hand, by employing procedures to minimize shattering, a greater supply of strong aggregate could be obtained where stable blocks, riprap, etc., is desired.

It is not possible to characterize an entire sandstone body as to its weathering behavior because of variations in lithology and differences in extent of alteration before excavation. However, with careful examination of natural outcrops in a limited area one can predict at least in a general way, what the weathering characteristics of the sandstone will be in that area. If exposures are poor, it might not be possible to make a meaningful evaluation until the rock is cored or excavation is initiated. With these preliminary studies, better planning for excavation and reclamation should be realized.

SECTION X

LABORATORY WEATHERING STUDIES

SIMULATED CHEMICAL WEATHERING WITH INTENSE AERATION

This part of the project was a modified continuation of studies initiated under EPA Project 14010 EJE, Mine Spoil Potential for Water Quality and Controlled Erosion (West Virginia University, 1971a). Selected rock chip samples, most of which had been previously ground to pass a 2mm. sieve, were placed in a 4x12x6 inch plastic container fitted with plastic lids. Each box had two openings constructed from 1/4" o.d. plastic tubing, one opening for air inlet and one for air and leachate exit. Moist air (produced by bubbling air through water) passed through each box for 3 1/2 days and was followed by dry air for 3 days. One half-day was used to leach the boxes and analyze the leachate. One kind of flyash (0.277 $CaCO_3$ equivalent) or pure $CaCO_3$ powder was added to selected samples as shown in Table 53. The second figure in the "Lime added" columns in Table 53 includes lime added to samples in Boxes B and H after 7 weeks. All boxes were inoculated with acid mine water from a deep mine to provide the essential microorganisms for reduced sulfur and iron oxidation. Two samples, A-A', 14b-7NS, (box 9) and Site HH, 24-NS., (box 2), are identical to samples A-A', 14b-7, (box 1) and Site HH, 24, (box 12), except that samples were not ground to pass a 2 mm. sieve; they represent "raw" rock chips as collected from the field.

Reaction products were periodically removed by adding 100 ml. of distilled, deionized water to each box, allowing contact with the sample for approximately ten minutes, and decanting into a centrifuge tube through the exit tube in the box. The leachate was then centrifuged to remove any "fines" and the volume of clear supernatant measured with a 100 ml. graduate cylinder. The centrifuged "fines" were dried for 2 days at 40°C and returned to the appropriate box. The volume of the recovered leachate was recorded and the resistivity was determined using an Industrial Instruments Model RC-1682 Wheatstone bridge and electrode with a cell constant of 0.01. Sulfate was determined using a Hach Portable Engineer's Laboratory and Hach reagent

Table 52

Simulated weathering of selected rock chip samples for a thirty-two week period.

Sample	Box #	Initial Total S (%)	% Initial Total S "Weathered" to Sulphates	$CaCO_3$ Equivalent (Initial) Tons/Thousand Tons	% of Initial Total $CaCO_3$ Equivalent "Weathered"
A-A',15-11	10	.310	8.74	2.11	11.12
A-A',14a-11	8	.260	10.13	7.68	8.19
Site HH-24-NS	2	.295	17.63	9.52	11.06
Site HH-24	12	.295	12.52	9.52	8.59
A-A',15-10	3	.290	4.08 (14 weeks)	19.48	2.86
A-A',14a-23	11	.275	3.31 (14 weeks)	40.81	1.48
A-A',15-15	4	.305	3.07 (14 weeks)	434.39	0.17
A-A',15-23	6	1.340	5.72	4.32	6.17
A-A',15-3	7	.545	3.87	1.73	6.13
A-A',14b-7NS	9	.805	3.53	10.85	3.81
A-A',14b-7	1	.805	3.63	10.85	3.86
A-A',14b-7	5	.800	1.70 (14 weeks)	80.69	0.83

Table 53

Simulated weathering of selected minewaste
and minesoil for an eleven week period.

Sample	Box #	Total S (%)	% Initial Total S "Weathered" to Sulphates"	CaCO$_3$ Equivalent Initial & Amendments Tons/Thousand Tons	Lime added Tons/Thousand Tons
Mine Waste (Composite of #'s 7, 9, and 10, Section XI)	A	1.02	13.76	- 5.01	0
	B	1.02	11.34	- 3.01 (4.99)	2 (+8 later)
	C	1.02	9.27	- 1.01	4
	D	1.02	5.00	2.99	8
	E	1.02	13.38	- 4.73	0.28 (100T flyash)
Flyash (Albright-3)	F	0.06	42.26	2.77	0
Sandstone (Sewickley)	G	12.70	2.88	-12.30	0
	H	12.70	2.70	-10.30 (5.70)	2 (+16 later)
	I	12.70	2.50	- 8.30	4
	J	12.70	1.72	- 4.30	8
	K	12.70	0.78	3.70	16
	L	12.70	3.19	-12.30	0
	M	12.70	2.57	- 8.30	4
	N	12.70	2.78	-12.02	0.28 (100T flyash)
Mine Waste #13 (Section XI)	O	2.00	3.83	9.01	0
	P	2.00	3.31	9.01	0

Sulfa-Ver III. The pH was determined by glass electrode and a Corning Model 12 pH meter. If the pH of the leachate was below 7.0, the sample was titrated to pH 7.0 (glass electrode) using standardized HCl.

For the data summary in Tables 52 and 53 the meq of acidity and mg of sulfur from the acid mine water added to each box was previously subtracted. The assumption was made that any sulfate present was in the form of $CaSO_4$, providing the basis for estimating % $CaCO_3$ equivalent "weathered".

Boxes 1 and 12 (Table 52) all contained sandstone or shale samples with inherent $CaCO_3$ equivalents which ranged from 1.73 to 434.39 tons/thousand tons of material. After 14 weeks, boxes 3, 4, 5, and 11 were terminated because carbonates were dominant over potential acidity and sulfate formation was uniformly slow, as illustrated in Figure 26, which is for box #3. Boxes 4, 5, and 11 produced similar trends and are not shown.

Trends for boxes 1, 6, and 10 are shown in Figures 27, 28, and 29. Boxes 2, 7, 8, 9, and 12 showed similar trends and are not presented. With boxes 1, 6, and 10, the maximum percent $CaCO_3$ equivalent weathered was 11.1% in box 10, and the pH of the leachate from these samples after 32 weeks remained at pH 7.0 or higher (Figure 27). From Figures 28 and 29 it appears that sulfate and alkalinity production are relatively stable.

As mentioned previously, boxes 2 and 9 are unground duplicate samples of boxes 12 and 1, respectively. As seen in Table 52, the unground samples show no consistent differences from the less than 2 mm. samples.

Boxes A through P contained untreated checks or samples treated with flyash or $CaCO_3$, Table 53. Samples A through E represented a composite of mine waste samples # 7, 9, and 10. Samples B and H received additional $CaCO_3$ (8 and 16 tons/thousand tons respectively) after 7 weeks. In all cases, samples treated with flyash or $CaCO_3$ show a decrease in percent S weathered (Table 53) when compared to the untreated sample. As shown in Figures 32 and 35 this is further substantiated by the inverse relationship between sulfate and $CaCO_3$ equivalent amendments to the samples. Titratable acidity (Figures 31 and 34) follows this same trend.

As expected, mine waste samples containing 1.02% S are producing less sulfate and titratable acidity than the sandstone samples containing 12.7% S (Table 53).

From these data, it appears that samples containing adequate amounts on inherent, available bases for neutralization (expressed as $CaCO_3$ equivalent) are more effective in preventing sulfate formation than similar samples that do not contain bases but have had $CaCO_3$ added. Presumably, added bases lack the intimate contact with the pyrite that typifies naturally-occurring constituents.

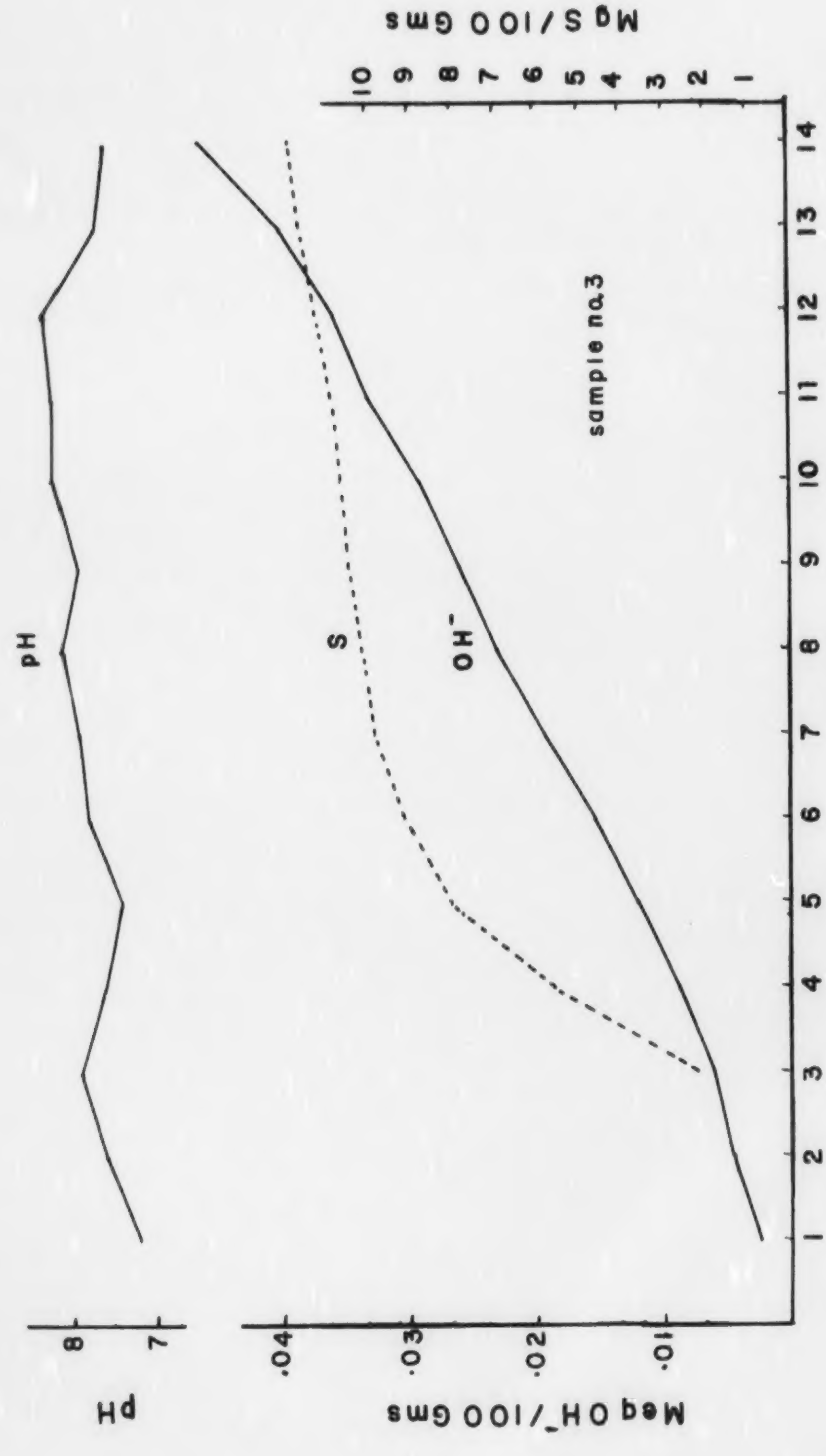


FIGURE 26. pH AND ACCUMULATIVE RELEASE OF SULFUR AND TITRATABLE ALKALINITY FROM SAMPLE A-A', 15-10

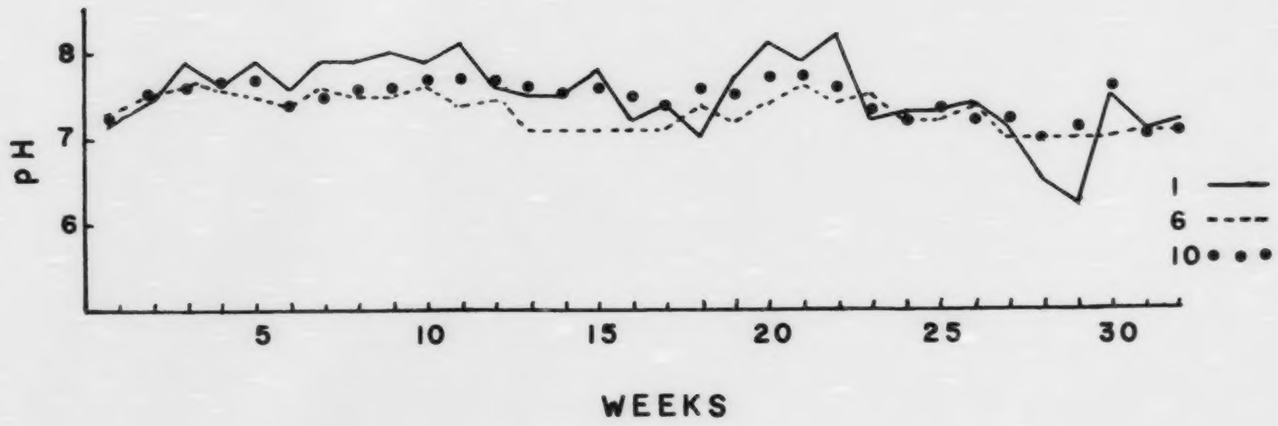


FIGURE 27. WEEKLY pH FOR SAMPLES A-A', 14b-7(BOX 1), A-A', 15-23(BOX 6), and A-A', 15-11(BOX 10)

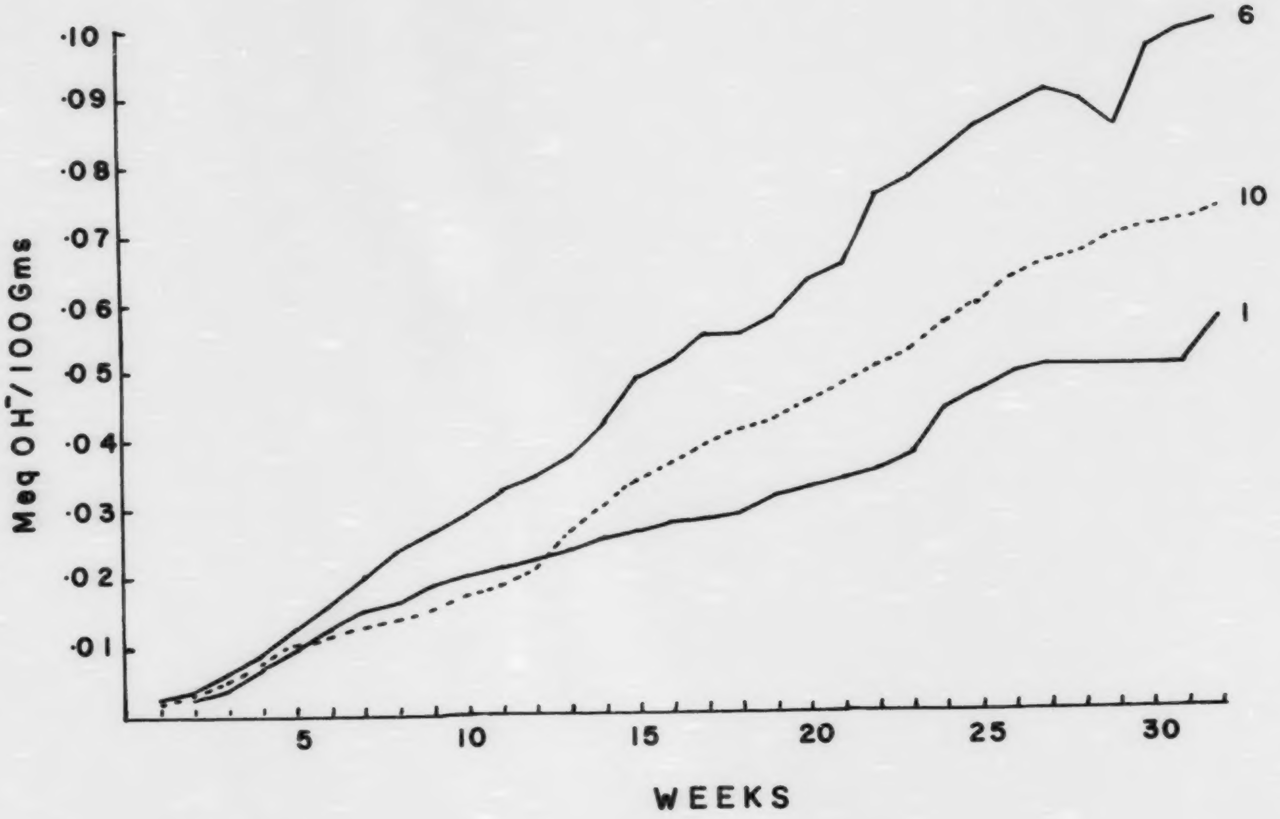


FIGURE 28. ACCUMULATIVE RELEASE OF TITRATABLE ALKALINITY FOR SAMPLES A-A', 14b-7(BOX 1), A-A', 15-23(BOX 6), and A-A', 15-11(BOX 10).

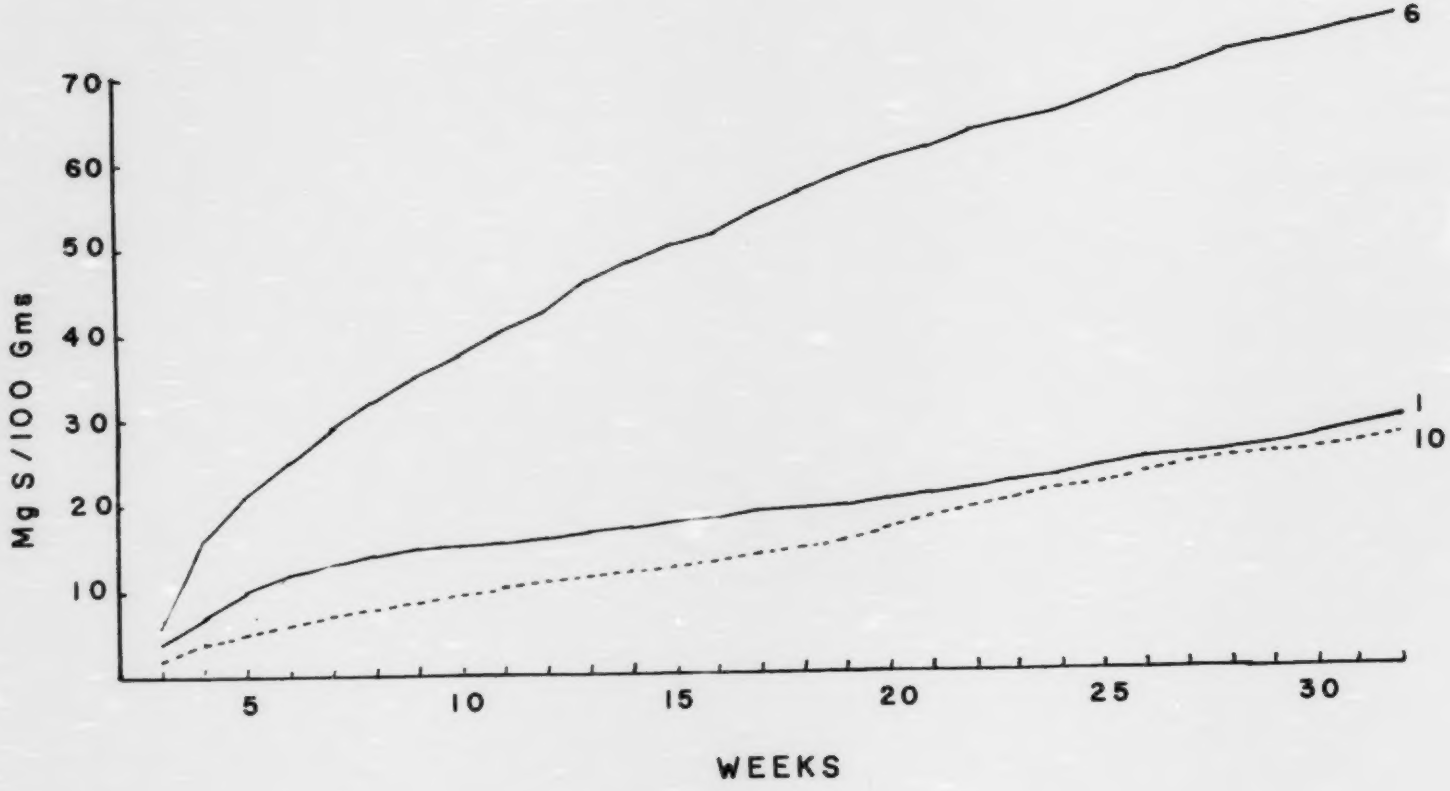


FIGURE 29. ACCUMULATIVE RELEASE OF SULFUR FROM SAMPLES A-A', 14b-7(BOX 1), A-A', 15-23(BOX 6), AND A-A', 15-11(BOX 10).

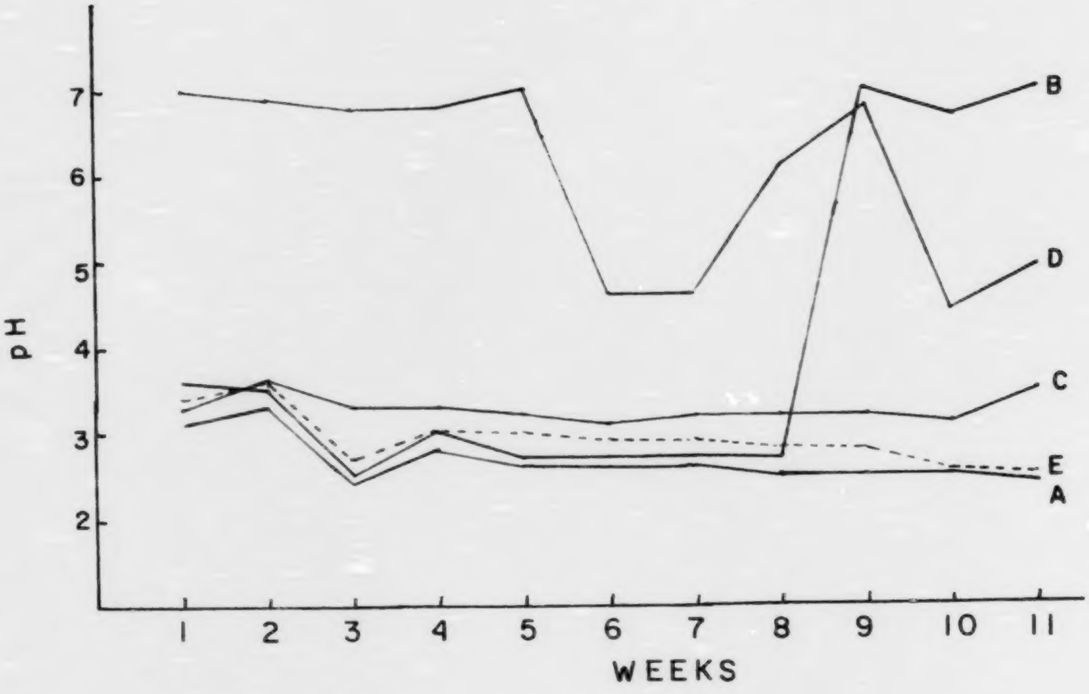


FIGURE 30. WEEKLY pH'S FOR MINEWASTE SAMPLES A, B, C, D, AND E, WITH VARIABLE LIME TREATMENTS.

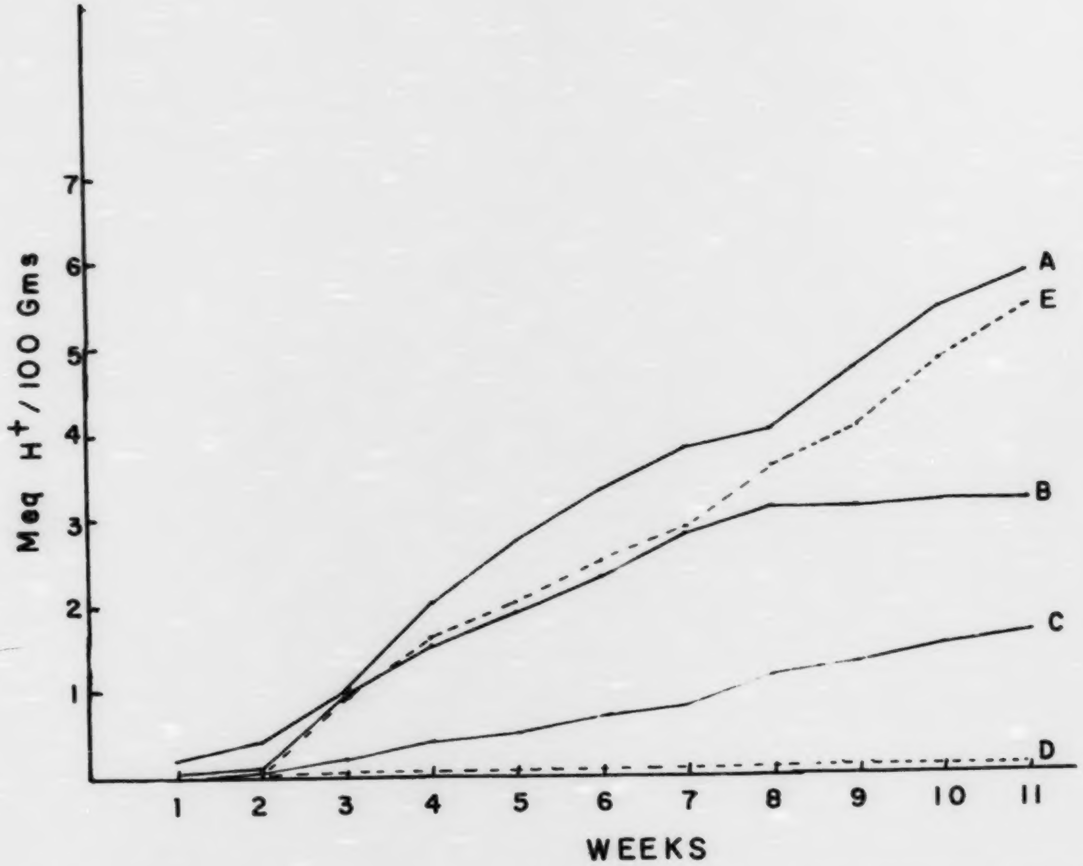


FIGURE 31. ACCUMULATIVE RELEASE OF TITRATABLE ACIDITY FROM MINEWASTE SAMPLES A, B, C, D, AND E, WITH VARIABLE LIME TREATMENTS.

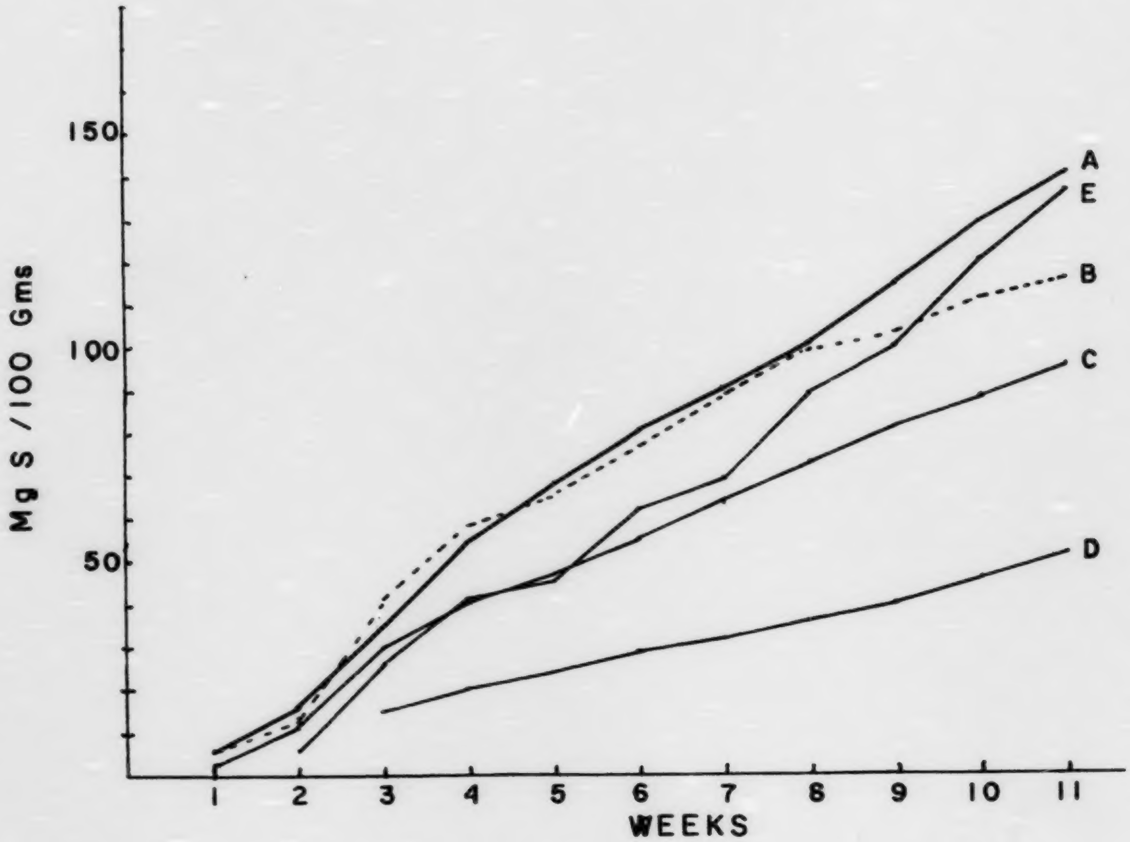


FIGURE 32. ACCUMULATIVE RELEASE OF SULFATE-SULFUR FROM MINEWASTE SAMPLES A, B, C, D, AND E, WITH VARIABLE LIME TREATMENTS.

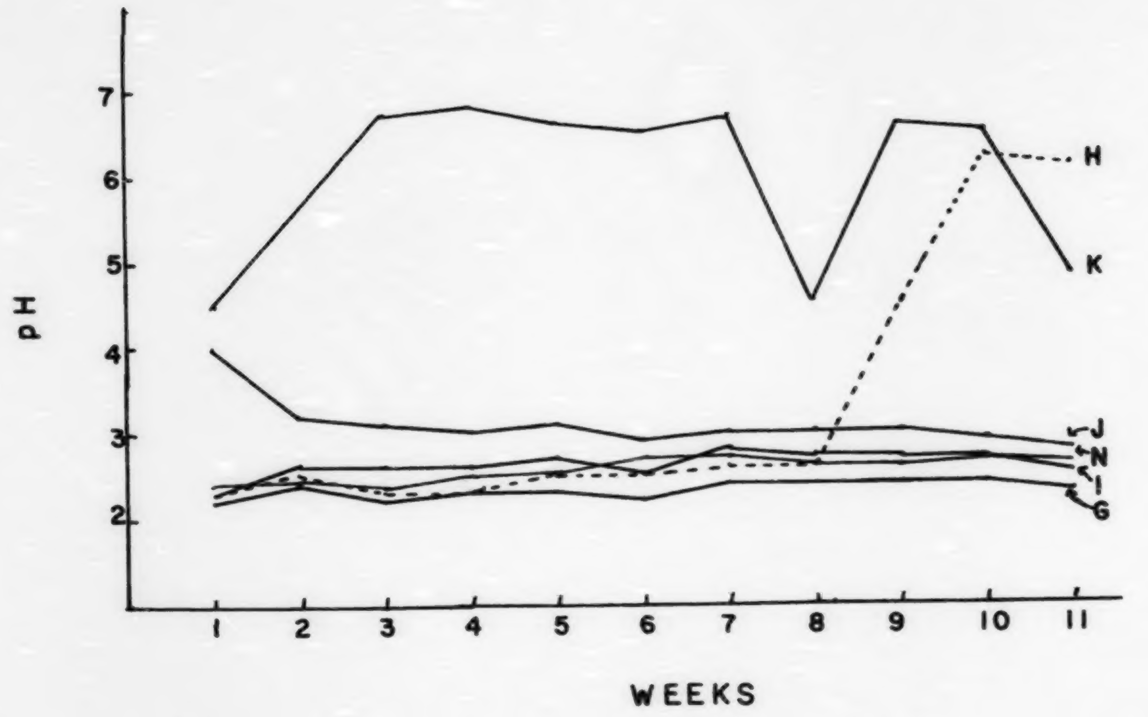


FIGURE 33. WEEKLY pH'S FOR SANDSTONE SAMPLES G, H, I, J, K, AND N, WITH VARIABLE LIME TREATMENTS.

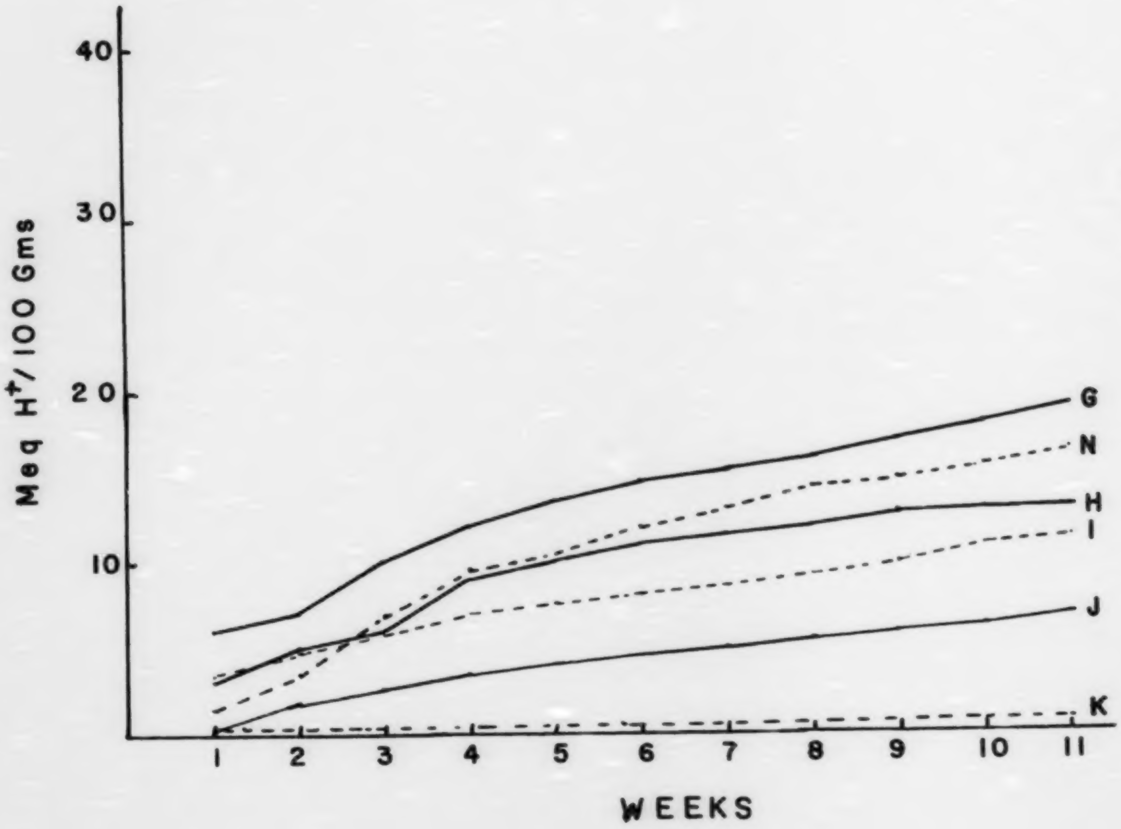


FIGURE 34. ACCUMULATIVE RELEASE OF TITRATABLE ACIDITY FROM SANDSTONE SAMPLES G, H, I, J, K, AND N, WITH VARIABLE LIME TREATMENTS.

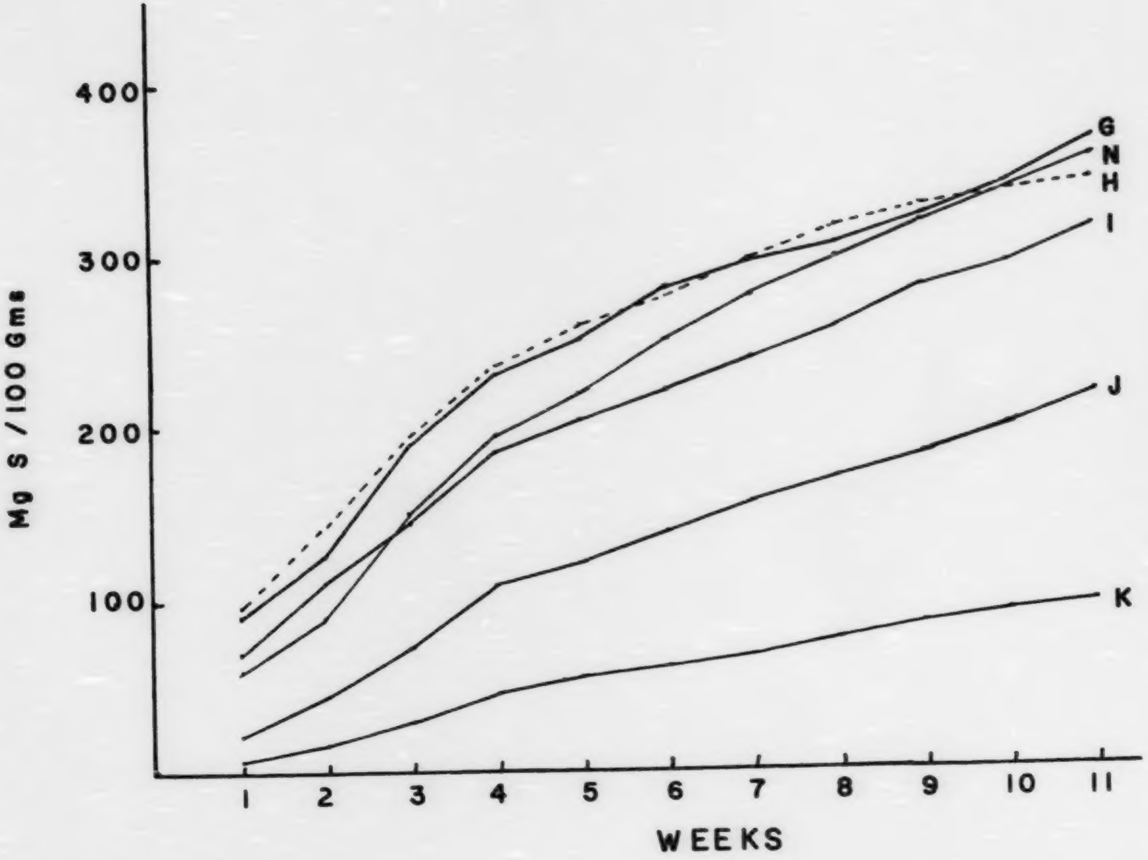


FIGURE 35. ACCUMULATIVE RELEASE OF SULFATE-SULFUR FROM SANDSTONE SAMPLES G, H, I, J, K, AND N, WITH VARIABLE LIME TREATMENTS.

SIMULATED CHEMICAL WEATHERING WITH NATURAL AERATION

Natural acid sandstone minesoil from Site KK (Appendix E) was mixed with several rates of agricultural limestone and kept moist in glazed 9-inch deep pots in the laboratory at temperatures near 70°F (plus or minus 5°F) for 112 days. Then, as a measure of the influence of modified acidity on oxidation of pyritic sulphur to sulphates, the percent of total sulphur was determined and plotted against pH of the minesoil. Each point is an average for 4 replicate pots.

As shown in Figure 36, sulphate production correlated negatively with pH. This result supports the belief that liming of this kind of minesoil tends to reduce the rate of pyrite oxidation and formation of sulphates. It may be that this effect of pH is an indirect result of reduced microbiological activity with increasing pH, since Thiobacillus organisms are known to respond to pH in the manner shown (Zuberer, 1972).

SIMULATED PHYSICAL WEATHERING

The elimination of water pollution from minesoils has focused attention on the chemical properties of stripmine overburden, not only the acid generation abilities, but also the nutrient supplying capabilities of the material for plant growth. In the short term, chemical properties are the most important factors associated with minesoil stabilization and prevention of water pollution; however, once this objective has been attained, the long term objectives for this land are usually dictated by the physical properties of the minesoils. The enormous costs of modifying minesoils after the initial placement of overburden materials indicates that both objectives should be satisfied during the initial reclamation phase; thus, both a chemical and physical characterization of overburden materials should be completed before placement of spoil materials is undertaken.

Until recently there has been no intensive study of physical properties of overburden materials, and to fill this need, work on several different methods was undertaken. One result of this work was the Physical Weathering Potential measurement outlined in Section VI of this report. This method can provide valuable information concerning future soil development such as texture of soil, time for development of soil separates and types and amount of coarse fragment that may develop. This information combined with chemical characterizations (e.g., neutralization potential and soil test data) can be utilized for preplanning a surface mine to obtain maximum benefits from our coal and land resources. This type of information can also be a useful tool for preplanning disturbed areas other than coal mines.

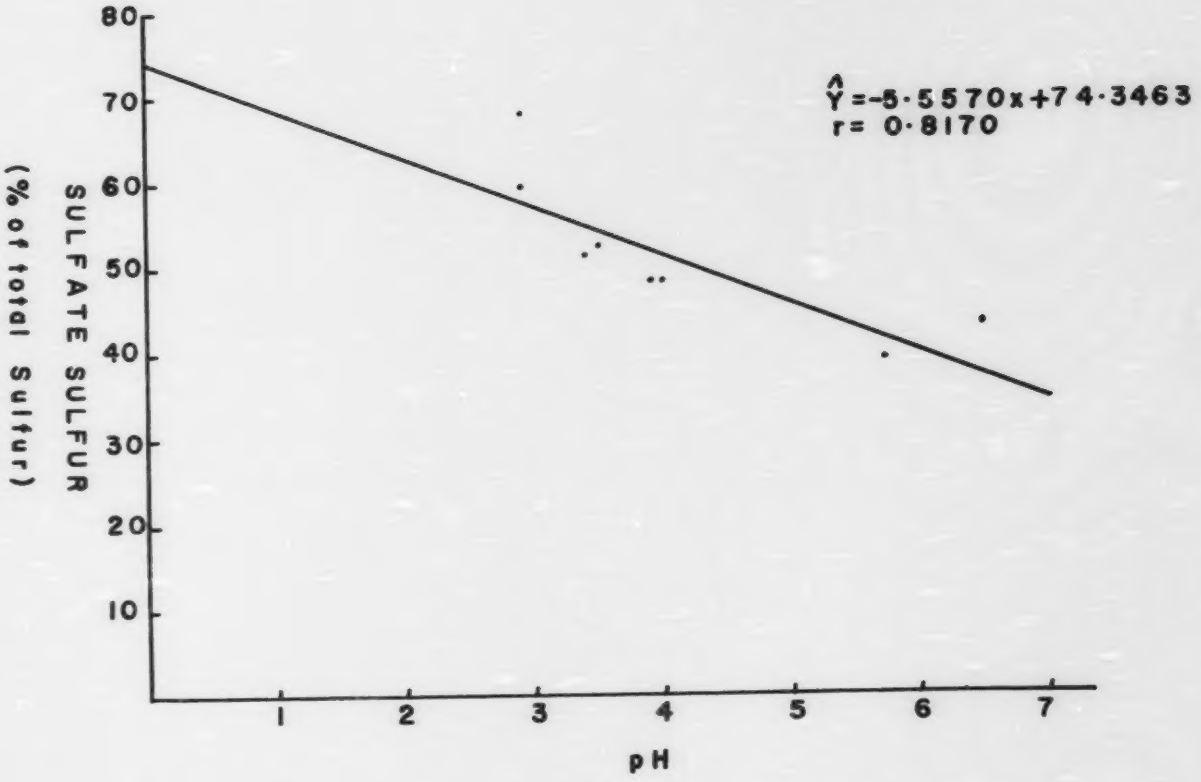


FIGURE 36. RELATIONSHIP OF SULFATE-SULFUR FORMATION TO MODIFIED pH OF AN ACID SANDSTONE MINESOIL.

To illustrate the method of interpreting data obtained from the "Physical Weathering Potential" method and its utilization, three exploratory cores were analyzed. The data are reported in Tables 54, 55 and 56. Each table contains the depth from the land surface, rock type according to definitions in the Glossary, Section XVI , and the percentage of soil separates plus the coarse fragment percentage of the total sample. Coarse fragments (material which will not pass a 10-mesh sieve) are considered to be the material which has not weathered to soil size (less than 2 mm.) as defined by the Soil Science Society of America (Committee on Terminology, 1965).

The data in Table 54 emphasize two points: (1) the overburden material except for a 4.4 foot section at 101.6 feet from the land surface will weather slowly; (2) the resultant minesoil will have a sandy texture. There are no large sections of rock strata in this overburden which are more promising "top-soil" material than the 7.7 foot section starting at a depth 37.3 feet from the land surface. This section would yield a suitable material for placing on the top of the spoil area if the chemical properties are favorable. There is an indication (Table 21) that enough excess carbonates to neutralize any acid generated by the pyritic material is present in the rock strata. This interpretation is based upon the assumption that the area would only be disturbed to the Upper Freeport coal seam. If the material underlying the Upper Freeport coal was disturbed, then the recommendation would be modified to take advantage of the greater nutrient supply contained in the lower material.

The next site, B-B', 18, was only sampled beneath the Upper Freeport coal seam. If this material were exposed by surface mining, then the section from 275.5 to 296.0 feet would be the preferred material to place upon the top of the spoil. The data indicate that it will weather more rapidly than material underlying it and will result in a loamy minesoil. Also the acid base account (Table 22) indicates the presence of an excess of carbonates after all the acid is neutralized. Normally, the mudrock and shale weather quickly but at depths lower than 322.0 feet at this site, they seem to be resistant to change. One reason for this could be the intense pressure to which they have been subjected as evidenced by the prominent slickensides found in the samples.

The third site, A-A', 12, is the best example of the usefulness of the method. This site consists dominantly of shales and mudrock which are commonly found above the Redstone and Pittsburgh coal horizons. It is suggested from the data in Tables 13 and 56 that there could be several sections of overburden which would be suitable material to be placed on the surface of the resulting minesoil. The 9.5 foot section starting at a depth of 18 feet will weather rapidly resulting in a loamy textured soil with a large excess of bases to provide a near-neutral pH.

Table 54

Mechanical composition of Upper Freeport test core samples, from Site B-B',16, following artificially induced physical weathering.

Depth	Rock Type	Coarse Fragment %	Sand %	Silt %	Clay %
18.0- 23.6'	SS	99.7	-	-	-
23.6- 30.0'	SS	67.2	10.4	8.3	14.1
30.0- 35.0'	SS	97.9	-	-	-
35.0- 37.3'	SS	100.0	-	-	-
37.3- 39.0'	SS	37.3	41.5	8.1	13.1
39.0- 40.0'	SS	99.4	-	-	-
40.0- 40.7'	SS	89.4	0.2	4.0	6.3
40.7- 40.9'	SS	46.5	35.1	8.9	9.5
40.9- 42.3'	SS	71.2	8.5	15.4	4.8
42.3- 45.0'	SS	86.0	2.8	8.4	2.8
45.0- 46.0'	SS	99.8	-	-	-
57.1- 62.2'		Upper Freeport coal seam			
75.0- 80.0'	SS	99.4	-	-	-
80.0- 82.9'	SS	99.1	-	-	-
82.9- 85.0'	SS	100.0	-	-	-
85.0- 90.0'	SS	98.3	-	-	-
90.0- 91.0'	SS	100.0	-	-	-
91.0- 96.0'	I	97.0	-	-	-
96.0- 97.5'	SH	71.0	4.1	9.5	15.2
97.5- 98.0	SH	81.2	10.5	4.9	3.4
98.0- 99.0'	SH	73.3	7.5	18.0	1.2
99.0-100.0'	SH	74.6	5.3	19.8	0.3
100.0-101.0'	MR	59.3	15.5	24.0	1.2
101.0-101.6'	CL	75.2	15.9	5.6	3.2
101.6-104.5'	MR	6.3	49.6	40.9	3.2
104.5-106.0'	MR	0.9	28.0	20.3	50.8
106.0-107.0'	MR	85.4	3.0	5.2	6.4
107.0-108.0'	MR	80.1	8.3	4.2	7.4
108.0-109.5'	MR	79.7	7.9	6.5	5.9
109.5-111.5'	SH	96.9	-	-	-
111.5-113.0'	SS	94.3	0.9	3.3	1.5
113.0-115.0'	SS	100.0	-	-	-
115.0-117.0'	SS	100.0	-	-	-
117.0-120.0'	SS	99.3	-	-	-
120.0-122.0'	SS	100.0	-	-	-

Table 54 continued,

122.0-125.0'	SS	100.0	-	-	-
125.0-130.0'	SS	100.0	-	-	-
130.0-135.0'	SS	100.0	-	-	-
135.0-140.0'	SS	100.0	-	-	-
140.0-145.0'	SS	100.0	-	-	-
145.0-149.5'	SS	100.0	-	-	-
149.5-150.0'	SS	100.0	-	-	-

Table 55

Mechanical composition of test core of Upper and Middle Kittanning overburden and underlying materials, from Site B-B',18, following artificially induced physical weathering.

Depth	Rock Type	Coarse Fragment %	Sand %	Silt %	Clay %
272.0-275.5'		Upper Freeport Coal			
277.5-278.5'	MR	60.2	8.6	17.9	13.3
278.5-280.0'	MR	34.0	31.4	20.5	14.2
280.0-281.0'	SH	97.9	-	-	-
281.0-282.0'	MR	41.4	11.3	27.0	20.2
282.0	MR	39.7	17.5	22.5	20.3
	MR	89.4	3.8	3.4	3.5
	MR	93.7	2.7	2.4	1.2
-296.0'	MR	97.7	-	-	-
296.0-298.5'	SH	94.5	2.9	1.3	1.2
298.5-299.0'	SS	100.0	-	-	-
299.0-302.5'	I	-	-	-	-
302.5-303.5'	SS	100.0	-	-	-
319.5-321.5'	SS	100.0	-	-	-
322.0-323.0'	MR	90.5	1.7	3.7	4.1
323.0-326.0'	SS	100.0	-	-	-
326.0-326.5'	MR	85.9	3.9	6.8	3.3
326.5-	SH	99.5	-	-	-
-333.5'	SH	97.8	-	-	-
334.0-336.0'	SH	100.0	-	-	-
336.0-339.5'	SH	99.9	-	-	-
339.5	SH	100.0	-	-	-
	SH	96.7	1.4	0.7	1.1
	SH	100.0	-	-	-
	I	83.7	3.7	8.0	4.6
	I	100.0	-	-	-
	I	94.8	1.9	2.6	0.7
-354.0'	SH	99.5	-	-	-
354.0-356.0'	SH	100.0	-	-	-
356.0-	SH	98.5	-	-	-
-360.0'	SH	99.9	-	-	-
-360.5'	SH	Upper Kittanning Coal Seam 3 inches			
366.0-	SH	100.0	-	-	-
-372.0'	SH	99.1	-	-	-
-373.0'		Middle Kittanning Coal Seam 1 foot			

Table 55 continued,

376.0-	I	100.0	-	-	-
-379.0'	I	100.0	-	-	-
379.0-380.0'	SS	100.0	-	-	-
380.0-	I	100.0	-	-	-
-385.0'	I	99.4	-	-	-
385.0-386.5'	I	100.0	-	-	-
386.5-	I	100.0	-	-	-
-390.5	I	99.5	-	-	-
390.5-	I	100.0	-	-	-
	I	100.0	-	-	-
-399.5	I	99.9	-	-	-
400.0-	MR	96.6	0.5	0.8	2.1
	MR	94.3	0.8	1.8	3.1
-406.0'	MR	94.5	1.4	1.4	2.6

Table 56

Mechanical composition of test core of Redstone and Pittsburgh overburden materials, from Site A-A',12, following artificially induced physical weathering.

Depth	Rock Type	Coarse Fragment %	Sand %	Silt %	Clay %
18.0-	MR	69.5	5.6	16.3	8.5
- 22.9'	MR	46.0	9.7	24.6	19.7
22.9- 24.8'	MR	17.6	33.3	19.5	29.6
24.8-	MR	13.2	25.6	28.4	32.8
- 27.5'	MR	9.2	32.5	14.7	43.6
27.5- 34.5'	SS	92.6	2.3	3.4	1.7
34.5- 35.8'	SH	67.1	4.3	11.6	17.0
35.8- 39.0'	SS	88.9	2.1	5.6	3.4
39.0- 39.8'	MR	36.2	28.9	18.2	16.7
39.8- 44.0'	SS	99.1	-	-	-
44.0-	SH	45.8	13.9	20.3	20.0
	SH	11.4	10.7	33.1	44.8
	MR	6.9	17.7	26.0	49.4
	MR	15.8	19.2	21.1	43.9
	MR	0.1	17.6	39.7	42.6
	MR	0.6	15.9	43.6	39.9
	MR	8.6	24.3	35.6	31.4
	MR	35.9	14.8	28.9	20.3
- 63.0'	MR	28.3	16.7	30.8	24.3
63.0- 66.3'	SS	89.6	10.7	0.5	-
66.3- 69.3'	SH	31.4	8.5	29.3	30.7
69.3- 73.7'	I	96.2	2.1	1.3	0.4
73.7- 75.7'	SH	44.8	5.7	22.0	27.5
75.7-	SH	99.6	-	-	-
- 90.0'	I	86.8	2.8	3.2	7.2
90.0-	MR	35.8	15.2	20.4	28.5
	SH	86.1	2.6	6.5	4.8
- 99.0'	SH	78.4	4.5	10.5	6.6
99.0-104.0'	MR	11.6	28.4	33.2	26.7
104.0-106.1'	MR	59.5	4.3	27.3	8.8
106.1-108.8'	MR	17.8	12.5	42.1	27.5
109.6-	MR	31.4	26.1	16.8	25.6
	MR	52.7	11.1	10.4	25.7
-118.0'	MR	47.6	13.6	10.6	28.2
118.0-	SH	97.1	1.0	1.8	0.1
-131.5'	MR	50.1	16.0	26.5	7.3

Table 56 continued

131.5-	SH	77.4	3.3	13.9	5.4
	SH	31.3	13.6	36.0	19.0
-142.0'	MR	65.9	4.1	20.6	9.3
142.0-144.5'	SH	1.3	0.4	67.5	30.8
144.5-	MR	88.9	4.2	4.4	2.4
	MR	99.8	-	-	-
	I	71.4	11.0	10.3	7.3
-157.9'	I	93.8	3.1	2.6	0.5
157.9-164.7'		Redstone coal section missing			
164.7-	SH	99.8	-	-	-
-171.5'	SH	2.4	13.3	45.7	38.6
171.5-175.5'	I	100.0	-	-	-
175.5-178.5'	I	62.4	10.2	16.2	11.2
178.5	LS	98.2	0.7	0.7	0.4
	SH	86.4	4.1	4.3	5.3
	MR	5.0	19.5	33.1	42.4
-189.3'	LS	67.1	6.0	13.6	13.2
189.3-190.8'	MR	1.4	15.6	34.6	48.3
190.8-192.3'	MR	97.6	-	0.5	1.9
192.5-	MR	34.7	13.1	25.3	26.8
-199.0'	MR	5.0	22.4	32.8	39.8
199.0-200.0'	I	99.4	-	-	-
		Position of Pittsburgh coal			

Another 19 foot section of material starting at the 44 foot depth would also be considered for placement on the top of the minesoil; however, this material disintegrates rapidly resulting in a clay dominated soil which would not be a desirable as a loamy textured soil for certain types of future uses. Also, the acid-base balance (Table 13) of this section is not comparable to the section of overburden previously mentioned.

A third section which should be considered as "top-soil" material is the mudrock extending from 99.0 to 118.0 feet below the land surface. This material tends to be influenced by the clay fraction and it also contains sufficient bases to eliminate any acid problem which may arise. These sections of the overburden could be mixed with other strata or the 18 feet of material (not available for analysis) that starts at the land surface to get a loamy textured soil if the resultant chemical properties were favorable.

The Physical Weathering Potential does not project the harsh grinding (by machinery) or severe chemical weathering which exists under natural conditions in the field. This method is a mild weathering procedure; therefore, materials which disintegrate in the laboratory would be more easily weathered in the field under the harsher conditions.

SECTION XI

CHARACTERIZING MINE WASTES

Discussions in this section include materials categorized by others as "gob", "tailings", "refuse heaps", "slate dumps", "red dog", "yellow boy", "mine refuse", "mine waste", etc., and includes flyash and other reputed waste materials resulting from coal mining and byproducts of such operations as water treatment or burning operations. Indeed the various names used are somewhat indicative of the wide variety of materials resulting and considered as unusable after the mining operation. Realistically, much of the more common mine waste materials categorize easily into (1) discarded coal partings, roof shale fractions, or highly pyritic shale lumps, or impure coal associated with cleaning or purifying coal into a readily marketable produce; or large piles (perhaps covering many acres and being many tens of feet in height) of this material in varying stages of being leached, weathered, or oxidized from spontaneous combustion; (2) flyash, the residue remaining from burning coal in an electric generating plant; tonnage wise this may amount to 10% of the amount of coal burned; and (3) mud, silt or elemental oxides resulting from natural or induced chemical reactions of salts dissolved in waters during treatment or stagnation in sediment ponds. Environmentally, the first category of mine waste materials is probably considered most significant, followed by flyash disposal or utilization, with water treatment residues being small mostly local problems.

Attempts to vegetate mine waste areas frequently involve either extreme soil acidity or fertility imbalances or both, and limited capacities to retain available water because of oily, water repellent surfaces of some of the carbolithic materials. Therefore most of the studies carried out under this project have been aimed toward evaluating the suitability of the mine waste material for plant growth.

Sampling mine waste areas has usually been carried out cooperatively with Soil Conservation Service personnel who have particular knowledge of areas with difficult vegetation problems. Sample processing was carried out using methods adapted for minesoils (Section VI). Most mine wastes would be classified in Carbolithic Subgroups of minesoils (Section V).

Estimates of the acid producing potential of minesoil or mine waste materials are frequently inaccurate if total sulfur content of the sample is used in the determination. Upon exposure to the atmosphere a substantial proportion of the pyrite originally present may have weathered to sulfate, rendering the subsequent acid potential related to the quality of unoxidized pyrite remaining in the material. In addition pyrite oxidation may vary greatly with respect to depth from the surface, therefore care needs to be exercised in relating analytical results to either a thin surface layer of waste, or to deeper, less oxidized material. The procedure given in Section VI for sulfate removal has been useful in obtaining an accurate characterization of these materials.

Derivation of an Acid-Base Account (see Section VII) for various mine wastes has aided in estimating the degree of ammendment necessary, or whether simple covering with more desirable soil or rock material was more desirable. Table 57 shows data for several typical mine waste materials. These and other data show the presence of some neutralizing bases, although these materials frequently are acidic. Where laboratory measurements indicate a calcium carbonate deficiency of 5 to 10 tons per thousand tons, or higher, serious consideration should be given to covering with more acceptable material (frequently available from a local surface mine area) unless high rates of lime can be incorporated into deep surface layers to assure neutralization and permit successful vegetation.

Empirical studies of acid formation from mine waste materials treated with varying amounts of calcium carbonate (see Section X) show the usefulness of high amounts of lime in reducing acidity (Table 53). Limited data also confirm that applications of flyash neutralize acid or reduce acid generation in proportion to calcium carbonate equivalent added, as measured by the neutralization potential method.

Soil Test Laboratory analyses of numerous mine waste samples indicate that potassium is nearly always required to increase fertility.

Tests for available phosphorus have frequently yielded uninterpretable results, because of interference by soluble iron or some other chemical species with the determinative test. Experimentation has shown sodium bicarbonate extraction method for phosphorus to be substantially more reliable and less subject to interference than other phosphorus tests.

Table 57.

Sample characterization and Acid-Base Account of selected mine waste samples from Surface Mining Province I (Boone Co.)

				Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
(Sample #)	Intensity if Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
1	0	10 YR 6/3.5	.020	0.62	0.78		0.16
2	0	10 YR 6.5/3	.055	1.72	0.00	1.72	
3	0	2.5 Y 6/3	.220	6.88	-1.28	8.16	
4	0	10 YR 6/3	.030	0.94	2.58		1.64
5	0	2.5 Y 5.5/3	.160	5.00	1.29	3.71	
6	0	5 YR 5/2	.630	19.69	8.76	10.93	
7	0	5 Y 4.5/1	.350	10.94	1.29	9.65	
8	0	5 Y 4/1	.500	15.62	11.07	4.55	
9	0	5 Y 4/1	1.550	48.44	-3.34	51.78	
10	0	5 Y 4/1	1.000	31.25	-7.72	38.97	
11	0	5 Y 3.5/1	.650	20.31	0.78	19.53	
12	0	5 Y 3/1	.550	17.19	-1.02	18.21	
13	0	5 Y 2.5/1	2.000	62.50	9.01	53.49	
14	0	5 Y 2.5/1	.900	28.12	-1.02	29.14	
15	0	2.5 Y 2/0	2.250	70.31	-7.97	78.28	

1. Island Creek, Top of #4 Arial Tram, Stowe.
2. #5 Arial Tram, Above Mine Dump.
3. #5 Truck Dump. Above Cleaning Plant.
4. Island Creek, #1 Dump, Cover Material
5. Powellton #3, Cover Material.
6. Island Creek Coal Company, #1 Dump, Red Dog.
7. Island Creek, #4 Mine Dump, below Road, Stowe.
8. Fanco Preparation Plant, Refuse Pile.
9. #5 Arial Tram, Spoil Material.
10. Powellton #1, Old Dump, Sheep.
11. Island Creek #4 Arial Tram Dump.
12. Island Creek, Truck Dump above #5 Cleaning Plant.
13. Island Creek, #1 Mine.
14. Powellton #3, Spoil Material.
15. Powellton #2, Lick Branch.

Table 58.

Soiltest results for selected mine waste samples from Surface Mining Province I (Boone Co.).

		Tons	per Thousand Tons of Material Pounds			
Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
1	4.6	2.25	25	175	280	84
2	4.0	3.75	24	165	160	66
3	3.8	5.20	35	209	1600	600+
4	4.8	1.50	56	203	1240	372
5	4.2	2.25	17	197	1000	252
6	6.6	0	80?	624+	4000+	282
7	4.6	1.50	43	262	1760	150
8	6.5	0	94	312	3080	600+
9	3.4	6.75	10	66	3600	438
10	2.7	8.25	12	19	1320	396
11	4.3	3.00	35	265	1120	276
12	4.0	2.25	8	78	1280	210
13	7.1	0	58	287	4000+	516
14	4.0	0.75	18	84	2440	198
15	2.8	7.50	153?	41	2400	498

The coal-burning power plant industry byproduct, flyash, has received much attention in recent years as a potentially useful amendment for disturbed land areas, including surface mine spoil areas. Although characterization of this material by total chemical analyses and particle size distributions may be helpful, measurements of potentially useful plant nutrients or neutralizing potential have not commonly been practiced except in relatively infrequent agronomic evaluations. Table 59 shows the widely varying range of Neutralization Potential exhibited by several flyashes evaluated by methods described in Section VI. Obviously even very large applications of material similar to the Albright flyashes, for example, will still require additional agricultural limestone to neutralize acidity; whereas other flyashes apparently contain several percent calcium carbonate equivalent neutralizing power. Sulfur analyses reported here are total sulfur. Although these samples were not leached to remove sulfates, it is expected that a major proportion of the total sulfur present in flyashes is present as sulfate. Therefore the acid-producing potential should be very low, even though sulfur is present up to several tenths of a percent.

Plant nutrient content of most of the flyashes analyzed in this instance appears moderate (Table 60), however this will necessarily be decreased by dilution when any of the flyashes are applied as an amendment to a material of lower available nutrient content. The above discussion suggests analyses of flyashes, by procedures more appropriate to revegetation requirements than total chemical analyses. Such analyses prior to application to a spoil area may show significant advantages in applying flyash from certain powerplants to specific areas that could best benefit from the properties of a specified ash.

Table 59

Sample characterization and Acid-Base Account of several Flyash samples.

					Tons of $CaCO_3$ Equivalent per Thousand Tons of Material			
Depth	(Sample #)	Intensity of Fiz	Color	%S	Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
	1	0	2.5 Y 3/0	.242	7.56	2.27	4.29	
	2	0	5 Y 5/1	.055	1.72	8.59		6.87
	3	0	5 Y 5/1	.090	2.81	5.56		2.75
	4	0	5 Y 5/1	.145	4.53	6.32		1.79
	5	0	5 Y 5/1	.110	3.44	1.53	1.91	
	6	0	5 Y 5/1	.080	2.50	1.53	.97	
	7	1	5 Y 6/1	.410	12.81	35.60		22.79
	8	1	5 Y 6/1	.415	12.97	34.83		21.66
	9	0	10 YR 3/1	.325	10.16	11.63		1.47
	10	0	5 Y 5/1	.060	1.81	2.77		0.86
	11	-	-	-	-	41.58		
	12	-	-	-	-	17.57		
	13	-	-	-	-	11.38		

1 Anthracite VGI
2 Willow Island
3 Powhatan Point
4 Mount Storm
5 Albright - A
6 Albright - B
7 Fort Martin - A
8 Fort Martin - B
9 Rivesville
10 Forestry Flyash (Albright-C)
11 Harrison Station
12 Rivesville Station (dark)
13 Rivesville Station (light)

Table 60

Soiltest results for several Flyash samples.

			per Thousand Tons of Material				
			Tons	Pounds			
Depth	Sample #	pH	Lime Req.	Phosphorus	Potassium	Calcium	Magnesium
	1	4.8	-	111	200	880	132
	2	7.6	-	153	134	4000+	288
	3	7.4	-	119	124	2920	172
	4	7.5	-	200	368	4000+	138
	5	4.8	-	94	281	960	42
	6	4.7	-	91	262	800	36
	7	9.1	-	128	390	4000+	588
	8	9.3	-	137	387	4000+	600+
	9	7.6	-	153	344	4000+	278
	10	5.4	-	174	228	2280	72
	11	9.9	-	132	452	4000+	600+
	12	9.3	-	102	365	4000+	600+
	13	8.2	-	128	477	4000+	600+

1 Anthracite UGI
2 Willow Island
3 Powhatan Point
4 Mount Storm
5 Albright - A
6 Albright - B
7 Fort Martin - A
8 Fort Martin - B
9 Rivesville
10 Forestry Flyash(Albright-C)
11 Harrison Station
12 Rivesville Station (dark)
13 Rivesville Station (light)

SECTION XII

EVIDENCES FROM OLD MINESOILS

CHEMICAL ANALYSES OF ROOT ENVIRONMENTS OF INVADING PLANT SPECIES

This work was undertaken to identify the naturally invading plant species found on two extremely acid stripmine spoils from Upper Freeport overburden; and, to determine if there were significant relationships between individual plant species and available nutrients in the root zone of these species. A secondary objective was to evaluate the barren areas within the two sites and determine if the lack of vegetation was due to low pH, depleted nutrient levels, or some other undetermined minesoil property.

Several spoils in Monongalia County, West Virginia have been in the planning stages of reclamation for several years. After grading of the spoil and soil tests were conducted, the sites were deemed suitable for plant establishment; however, a few months later when these spoils were checked again, the pH values had decreased to below 4.0. At this time the spoil was too acid for attempting revegetation, and periodic checks would be made to determine if the pH of those spoils had increased to an appropriate value (greater than 4.0) to permit successful revegetation of the area. Both sites used for this study were examples of the above situation.

Site QQ was derived from Upper Freeport overburden and covers 10.91 acres. The Soil Conservation Service classified the spoil as VIIIs3 due to its extreme acidity and extreme stoniness. The surface texture of the fines was sandy loam.

The spoil was leveled in December 1964 and was being planned for revegetation with autumn olive, Elaeagnun umbellata, and black locust, Robinia psuedoacacia L., by the Soil Conservation Service. When the pH was checked prior to spring planting in 1965, it was found that 80% of the spoil surface had dropped to a pH below 4.0. At that time it was felt that after a few more months the pH would increase. It has been checked several times since 1965 and the pH was still below 4.0.

Even though the spoil was still extremely acid in 1973, there were many plant species growing on the site. The primary species were identified as broom sedge, poverty grass, deertongue, redtop, black birch and red maple. Other species identified were: yellow poplar, sassafras, large tooth aspen, black cherry, black locust, sumac, domestic apple, goldenrod, sticktight, cinquefoil, greenbrier, white aster, Indian hemp, Spannish nettle, sheep sorrel, Joe Pye weed, thoroughwort, and several unidentified species.

Site SS was also derived from Upper Freeport overburden and covered 14.20 acres. The Soil Conservation Service classified this spoil VIIIs3. The surface texture was sandy loam and in some areas loamy sand. This spoil is not as stony as Site QQ.

The spoil was backfilled in November 1963 and was considered suitable for replanting. Autumn olive and black locust were to be planted in the spring of 1964, but when the pH was again checked, the values were too low. The same situation occured at Site QQ.

The barren areas of both sites were significantly lower in pH than areas where plants were growing. There was a distinctive difference between vegetated and barren areas, as there were no plants growing at a pH below 3.8 and there were no barren sites with a pH above 3.7. Red Maple was the most acid-tolerant species while redtop was significantly higher than all other species.

The potassium levels of both sites were in the medium range for all plants. This medium level of potassium is probably the single most positive factor in the establishment of plants on both sites. Broomsedge and deertongue areas had the highest potassium levels while barren areas were significantly lower than plant areas. Red maple and poverty grass showed the lowest potassium levels for plants on both sites.

Calcium and magnesium both exhibited the same basic distribution. Redtop areas had the highest levels of calcium and magnesium while barren had the lowest values. Red maple areas contained the lowest calcium and magnesium levels of the plant species and were not significantly different from barren areas. Poverty grass had the lowest levels of calcium and magnesium for the grass species and was not significantly different from red maple.

Both sites showed very low levels of phosphorus, with barren having the lowest values. Red maple was the most tolerant plant species at the lowest levels of phosphorus while soil averaged highest in phosphorus where broomsedge was growing, although the mean value was not significantly different from other plant species.

In the spring of 1973, Site SS had two major areas with natural vegetation. The barren areas are much larger than on Site QQ. The vegetation found on Site SS was similar to QQ, with only a few exceptions. Redtop was not found on Site SS and there were not as many forbs represented. Blackberry was abundant on one portion of Site SS and was not found on QQ. Overall, Site QQ had more plant species represented and there was a denser ground cover.

For the purpose of this study, there had to be at least eight individual plants of the same species at each site before it was considered as a primary species. At Site QQ, individual plants were selected at random except in the sampling of redtop. There were only 8 to 10 individual redtop plants on the entire site. Care was taken to select plants that were relatively the same size in order to minimize the variability among species. Any litter on the soil surface beneath or around the plant was removed to lessen the influence on the nutrient status of the soil sample. In case of grass species, each plant was totally harvested in order to obtain the soil from the roots at three inch depth. As for woody plants, the immediate soil surface was removed and the soil was obtained from around the roots to a depth of 3 inches.

Eight soil samples were obtained from roots of each of the primary invading species and from barren areas on both sites. Data from all the chemical analyses - pH, phosphorus (a and b), potassium, calcium, magnesium, and neutralization potential - were evaluated statistically. A standard t-test was used where variances were homogeneous and in cases where homogeneity was lacking, the t' test was used. All significant differences were noted at the 0.05 level.

Prior to the examination of soil chemical analyses for each of the plant species, it was noted that the pH values for vegetated areas were extremely acid - below 4.5. Also, the nutrient levels fall within the very low to low range, with one exception. Potassium levels on both sites were in the medium range, which probably partially accounts for the grass species doing as well as they did on these sites. Table 61 shows the ranges for phosphorus, both the dilute acid (a) and the sodium bicarbonate (b) methods, potassium, calcium, and magnesium. All values are in pounds per acre (2,000,000 lbs.).

Table 61. RANGES OF AVAILABLE PLANT NUTRIENTS CORRESPONDING TO LOW, MEDIUM AND HIGH AMOUNTS MEASURED IN THE LABORATORY.

	P (a)	P (b)	K	Ca	Mg
Very Low	0-24	-	0-39	0-399	0-49
Low	25-49	0-10	40-78	400-799	50-99
Medium	50-99	10-22	79-156	800-1999	100-249
High	100-174	22+	157-234	2000-3999	250-499
Very High	175+	-	235+	4000+	500+

Tables 62 and 63 show the mean values of eight observations for all the data from sites QQ and SS. All values are in pounds per acre, except for the neutralization potential values which are in tons of $CaCO_3$ equivalent per 1000 tons of material.

From this study it is evident that red maple tended to be the most tolerant plant species to low pH, potash, calcium and magnesium. The most tolerant of the grass species to low pH, calcium, potassium and magnesium on site QQ; was poverty grass, but on site SS poverty grass was not significantly different from the other grass species. Redtop exhibited the highest average pH, acid soluble phosphorus, calcium and magnesium and was significantly higher in pH than all other plant species. This study also confirms that the reason plants were not growing on the barren areas was the significantly lower pH and nutrient levels of those areas, not by chance, which was felt at the onset of this study.

SULFATE, PYRITIC, AND ORGANIC SULFUR SPECIES IN AGED MINESOILS

The initial investigation of the acid producing potential of three Upper Freeport minesoils (Sites QQ, RR, and SS, Appendix D) produced conflicting results which prompted a more detailed study of these 3 to 8 year old minesoils. The pH's of these samples were below 3.6 (Table 1) and the total sulfur measurements (Table 65) indicated a large amount of sulfur present in most samples. The potential acidity data, obtained by using the Peroxide method (West Virginia Univ., 1971a), indicated that only a small amount of oxidizable sulphur was present. To explain the paradoxical data, a fractionation of the total sulphur into the sulfate, pyrite and organic forms were accomplished using the A.S.T.M. method, designated D2492-66T (A.S.T.M., 1966), for removing the different fractions. The method was modified to permit the use of the Leco induction furnace to measure the total sulphur of each sample after each fraction had been removed and then the different fractions were determined by difference.

Table 62

Means and significant differences among all soil chemical analyses performed for each plant species on Site QQ. Values in same column followed by similar subscripts are not significantly different at the 0.05 level.

	pH	Phosphorus Dilute acid	Phosphorus $NaHCO_3$	Potassium	Calcium	Magnesium	Neutralization Potential
Broomsedge	4.03 bc	22.88 a	4.25 a	138.63 a	240 a	27.00 ab	-0.19 ab
Poverty Grass	3.96 c	21.75 a	3.75 a	96.63 bc	90 cd	11.25 c	-0.51 b
Deertongue	4.15 ab	22.75 a	4.00 a	137.88 a	100 bc	25.50 ab	-0.66 bc
Red Maple	3.94 c	16.00 b	3.38 a	80.63 c	55 d	8.25 cd	-1.00 b
Black Birch	4.08 b	21.13 a	4.75 a	97.13 b	135 b	15.75 b	-0.62 b
Redtop	4.26 a	23.25 a	3.75 a	106.25 b	320 a	74.25 a	+0.25 a
Barren	3.60 d	15.00 b	1.25 b	50.63 d	100 c	6.00 d	-1.53 c

Table 63

Means and significant differences among all soil chemical analyses performed for each plant species on Site SS. Values in same column followed by similar subscripts are not significantly different at the 0.05 level.

	pH	Phosphorus Dilute Acid	Phosphorus $NaHCO_3$	Potassium	Calcium	Magnesium	Neutralization Potential
Broomsedge	3.96 a	16.38 a	3.50 a	131.63 a	100.00 a	13.13 a	+0.41 a
Poverty Grass	4.01 a	14.50 a	1.38 b	95.25 b	80.00 ab	12.75 ab	+0.53 b
Deertongue	4.01 a	6.63 bc	3.13 ab	139.13 a	43.75 c	6.75 ab	+0.97 a
Red Maple	3.80 b	8.25 bc	3.25 a	86.38 b	21.25 c	3.75 bc	-0.10 c
Black Birch	4.09 a	6.25 c	2.00 ab	121.75 ab	48.75 ab	15.25 a	+0.97 a
Barren	3.45 c	10.25 b	1.25 b	57.25 c	21.25 c	2.50 c	-0.69 d

Table 64

Characterization and acid-base account of minesoil samples
from the 3 to 8 year-old sopil areas (QQ, RR, and SS)

Sample	Intensity of Fiz	Color	%S	Tons of $CaCO_3$ Equivalent per Thousand Tons of Material: Maximum Requirement (from %S)	Amount Present (Titration)	Amount Needed for Neutrality (pH7)	Excess $CaCO_3$ Equiv.
QQ 11	0	5 Y 6/1	.085	2.66	-3.94	6.60	
QQ 12	0	5 Y 5.5/1	.110	3.44	-3.69	7.13	
QQ 13	0	2.5 Y 6.5/2	.085	2.60	-2.95	5.55	
QQ 21	0	5 Y 4.5/1	.050	1.56	-2.95	4.51	
QQ 22	0	5 Y 4.5/1	.105	3.28	-2.13	5.41	
QQ 23	0	5 Y 5/1	.060	1.88	-2.95	4.83	
QQ 31	0	5 Y 4/1	.145	4.53	-3.69	8.22	
QQ 32	0	5 Y 4.5/1	.125	3.91	-2.95	6.86	
QQ 33	0	5 Y 4.5/1	.115	3.59	-2.95	6.54	
RR 11	0	2.5 Y 6.5/2	.060	1.88	-2.13	4.01	
RR 12	0	2.5 Y 6.5/2	.050	1.56	-1.66	3.22	
RR 13	0	2.5 Y 6.5/2	.090	2.81	-2.13	4.94	
RR 21	0	2.r Y 6/2	.075	2.34	-1.66	4.00	
RR 22	0	2.5 Y 6.5/2	.045	1.41	-3.94	5.35	
RR 23	0	2.5 Y 6.5/2	.060	1.88	-1.98	3.86	
RR 31	0	5 Y 6/1	.110	3.44	-1.66	5.10	
RR 32	0	5 Y 5.5/1	.120	3.75	-1.66	5.41	
RR 33	0	5 Y 5.5/1	.090	2.81	-1.66	4.47	
SS 11	0	5 Y 7/2	.015	0.47	-0.99	1.46	
SS 12	0	5 Y 7/2	.016	0.50	-1.21	1.71	
SS 13	0	5 Y 7/2	.043	1.34	-0.99	2.33	
SS 21	0	5 Y 7/2	.022	0.69	-1.66	2.35	
SS 22	0	5 Y 5.5/1	.070	2.19	-0.99	3.18	
SS 23	0	5 Y 6/1	.050	1.56	-1.66	3.22	
SS 31	0	5 Y 7/2	.021	0.66	-0.99	1.65	
SS 32	0	5 Y 7/2	.020	0.62	-0.99	1.61	
SS 33	0	2.5 Y 7/2	.013	0.41	-1.21	1.62	

Table 65

Fractionation of sulfur in 3 to 8 year old minesoils developed from 3 distinct types of Upper Freeport Overburden and fresh rock chip samples taken from the Bakerstown and Upper Freeport overburden.

	Total Sulfur			Forms of Sulfur as a percent of Total Sulfur Unleached			
		Leached					
Sample	Unleached %	HCl %	HCl, HNO_3 %	SO_4-S %	Pyrite-S %	Organic-S %	Predominant Rock Type
QQ 1-1	.480	.085	.045	82.3	8.3	9.4	Carbolith mixed with Mudrock and Sandstone
QQ 1-2	.380	.110	.054	71.0	14.7	14.2	
QQ 1-3	.210	.085	.038	59.5	22.4	18.1	
QQ 2-1	.245	.050	.043	79.6	2.8	17.5	
QQ 2-2	.340	.105	.064	69.1	12.0	18.8	
QQ 2-3	.330	.060	.048	81.8	3.6	14.5	
QQ 3-1	.235	.145	.142	38.3	1.3	61.7	
QQ 3-2	.340	.125	.107	63.2	5.3	31.5	
QQ 3-3	.170	.115	.094	32.3	12.3	55.3	
RR 1-1	.175	.060	.038	65.7	12.6	21.7	Sandstone (Low Chroma mixed with some Carbolith and Mudrock
RR 1-2	.170	.050	.028	70.6	12.9	16.5	
RR 1-3	.195	.090	.038	53.8	26.7	19.5	
RR 2-1	.185	.075	.032	59.4	23.2	17.3	
RR 2-2	.185	.045	.030	75.7	8.1	16.2	
RR 2-3	.165	.060	.032	63.6	17.0	19.4	
RR 3-1	.275	.110	.052	60.0	21.1	18.9	
RR 3-2	.370	.120	.062	67.6	15.7	16.7	
RR 3-3	.235	.090	.042	61.7	20.4	17.9	
SS 1-1	.120	.015	.012	87.5	2.5	10.0	Sandstone (High Chroma)
SS 1-2	.190	.016	.012	91.6	2.1	6.3	
SS 1-3	.155	.043	.016	72.2	17.4	10.3	

SS 2-1	.305	.022	-	92.8	-	-	mixed with
SS 2-2	.150	.070	.019	53.3	34.0	12.7	small amounts
SS 2-3	.225	.050	.040	77.8	4.4	17.8	of Mudrock
SS 3-1	.150	.021	.021	86.0	0	14.0	
SS 3-2	.135	.020	.016	85.2	3.0	11.8	
SS 3-3	.080	.013	-	83.7	-	-	
ST 9336	.685	.265	.153	61.3	16.3	22.3	
ST 9337	.585	.300	.230	38.5	17.1	39.3	Mixed
ST 9339	.395	.175	.120	55.7	13.9	30.4	amounts of
ST 9341	.285	.130	.102	54.4	9.8	35.8	Carbolith,
ST 9343	.195	.115	.036	41.0	40.5	18.5	Mudrock and
ST 9345	.130	.035	.028	73.1	5.4	21.5	Sandstone
T 1	.180	.130	.051	27.8	43.9	28.3	Mudrock
T 3	.340	.245	.040	27.9	60.3	11.8	Mudrock
T 15	1.370	1.270	.220	7.3	76.6	16.1	Mudrock
T 20	6.100	5.000	1.000	18.0	65.6	16.4	Carbolith
T 22	4.025	3.423	.450	34.8	73.9	11.2	Carbolith
L 12	.150	.135	.010	10.0	83.3	6.7	Sandstone
L 20	.265	.255	.030	3.8	84.9	11.3	Sandstone
L 34	.480	.465	.250	3.1	44.8	52.1	Sandstone
L 41	.855	.780	.100	8.8	79.5	11.7	Sandstone
L 44	1.790	1.570	.070	12.3	83.8	3.9	Mudrock

The data in Table 65 indicate that the sulfate S comprised 50% or more of the total sulfur content of all samples, plus QQ 3-2 were high in Organic-S and easily oxidizable organic matter (Table 4, Section VI). The samples from site SS were the lowest in total sulfur content and highest in the percentage of sulfate-S.

Only eight of the twenty seven samples had a higher percentage of pyritic-S than the organic-S form. The highest organic S percentages occured in the sample QQ 3-1, 3-2, and 3-3 which is indicative of the dominant rock type (carbolith) found at this site; however, sites RR and SS had a higher percentage of the organic-S fraction than would be expected since the minesoils at these sites are predominantly sandstone derived.

Some randomly selected minesoil samples (labeled ST) were analyzed and with the exception of ST-9343 the sulfate-S was the highest fraction with the organic-S being second, and the lowest fraction was pyritic. This is good evidence that weathering has proceeded after mining operations exposed the material to the atmosphere; but, the demonstration of a weathering zone in the rock strata before it is disturbed (West Virginia University, 1971a) would dictate that knowledge of the properties of this zone is essential before making any recommendations as to treatment of these sites.

Samples from sites T and L were analyzed in the manner previously described and the results (Table 65) indicate that fresh rock chip samples do undergo measurable weathering within a short time. Since only five samples from each rock chip core were analyzed only trends can be noted. The total sulfur content increases with depth (West Virginia Univ., 1971a) and there is sulfate-S present although the pyritic-S is the largest fraction.

The sulfate-S in overburden materials is negligible in comparison to the amount of pyritic-S present; therefore, a total sulfur measurement without first removing the sulfates would be sufficient when evaluating materials for their acid producing potential and suitability as "Top-Soil". However, when evaluating old minesoils which are to be revegetated, the amount of lime needed to completely neutralize the soil acidity and any future acid produced due to the oxidation of sulfides can not be determined by a total sulfur measurement, unless the sulfates are removed prior to the determination. The acid-base account (Table 64) for sites QQ, RR and SS indicates that except for five samples of site QQ, no more lime is need to completely neutralize any future acid production from the pyritic and organic-S fractions than is needed on some of the poorer, non-disturbed soils of West Virginia. If the sulfates had not been removed from these samples, the amount of lime thought to be needed would be much larger. These data provide the basis for general recommendations in West Virginia, that for old minesoils the maximum potential acidity estimated from total sulphur should be discounted from theoretical for pyritic sulphur, by factors of about 0.5 for low chroma materials, or 0.33 for high chroma minesoils. Obviously, these factors are approximations only, and more accurate results would require sulphur fractionation.

SECTION XIII

MINESOIL INTERACTION WITH PLANT COVERS AND MANAGEMENT

Observations throughout West Virginia indicate that establishment of vigorous vegetative covers on surface minesoils has improved dramatically during the past two years. It is not possible to say precisely what changes account for all improvements, but it appears that more attention to placement of different kinds of overburden is one significant change that has contributed. Another is increased use of lime and fertilizer treatments according to needs. Other improvements include higher seeding rates of the best adapted species, well-prepared seedbeds, and mulching.

Unfortunately, some changed practices have caused increased erosion, sedimentation, and damage to vegetative stands. One such practice is high wall elimination and establishment of long uninterrupted slopes. Such situations inevitably result in concentration of accumulating runoff into channels of flow with high eroding power, quickly causing rills and gullies. Another serious erosion-inducing practice is the covering of steep outslopes with relatively stone-free fine soil material. Runoff and erosion is much less severe where the top layer contains coarse fragments that are not readily moved by shallow runoff. Moreover, coarse fragments form natural stone mulches which help protect the fines and which retard concentration of runoff into channels.

Emphasis on establishing legumes requires continual attention, especially because of the demand for the quickest possible cover. Unfortunatley, the quickest, and most aggressive grasses tend to delay or prevent thick stands of legumes. Weeping love grass, in particular, grows so vigorously in warm seasons that legumes are retarded.

Recent work on surface liming illustrates the importance of working lime into acid minesoils and delaying fertilization and seeding long enough for the pH to be raised and especially for toxic aluminum to be converted to insoluble forms. Figure 37 illustrates the relationship between rate of surface-applied agricultural limestone, pH, and exchangeable aluminum. Minesoil samples taken at the one to two inch depth showed little change in amounts of exchangeable aluminum, and although the pH increased slightly, there was little movement of the lime down through the soil. Figure 38 shows the same situation where dolomitic limestone was applied. However, exchangeable aluminum appears to decrease more strikingly with increasing rate of lime than where predominantly calcitic lime was used.

Unquestionably, the partial failure of some seedings on strongly acid minesoils is more a matter of surface placement and not enough time for reaction, rather than any inaccuracy of recommended treatments . Surface liming, at best, doesn't eliminate toxic aluminum deeper than about an inch during the first six months. Lime must be worked in and allowed to react in order to permit added phosphorus to be effective, as well as to prevent aluminum toxicity.

There is still some tendency to forget that planting of non-leguminous shrubs or trees may fail because of nitrogen deficiency unless legumes are established as companion crops. One exception is European Black Alder, which, although not a legume, is believed to be capable of symbiotic nitrogen fixation. Other effective nitrogen fixing trees being used are black and bristly locust. These trees have special value because of nitrogen, and should never be judged solely on other values (or lack of values) of the trees themselves. These observations and conclusions lead back, inevitably, to the quality of overburden and final placement in the minesoil. When favorable, non-toxic material with good water-holding capacity is placed on the surface, there is little difficulty in growing vigorous legumes, with little or no liming and fertilizing problem.

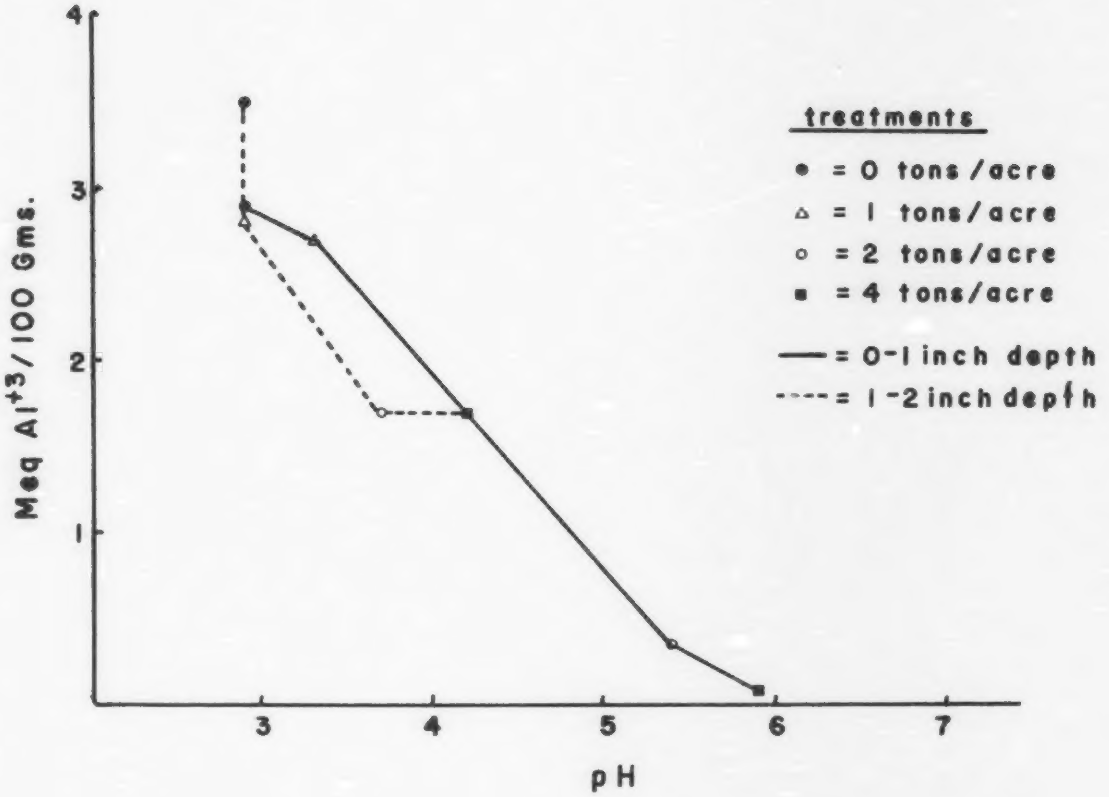


FIGURE 37. pH VERSUS EXCHANGEABLE ALUMINUM AT TWO DEPTHS IN SANDSTONE MINESOIL, SIX MONTHS AFTER SURFACE LIMING WITH STANDARD AGRICULTURAL LIMESTONE.

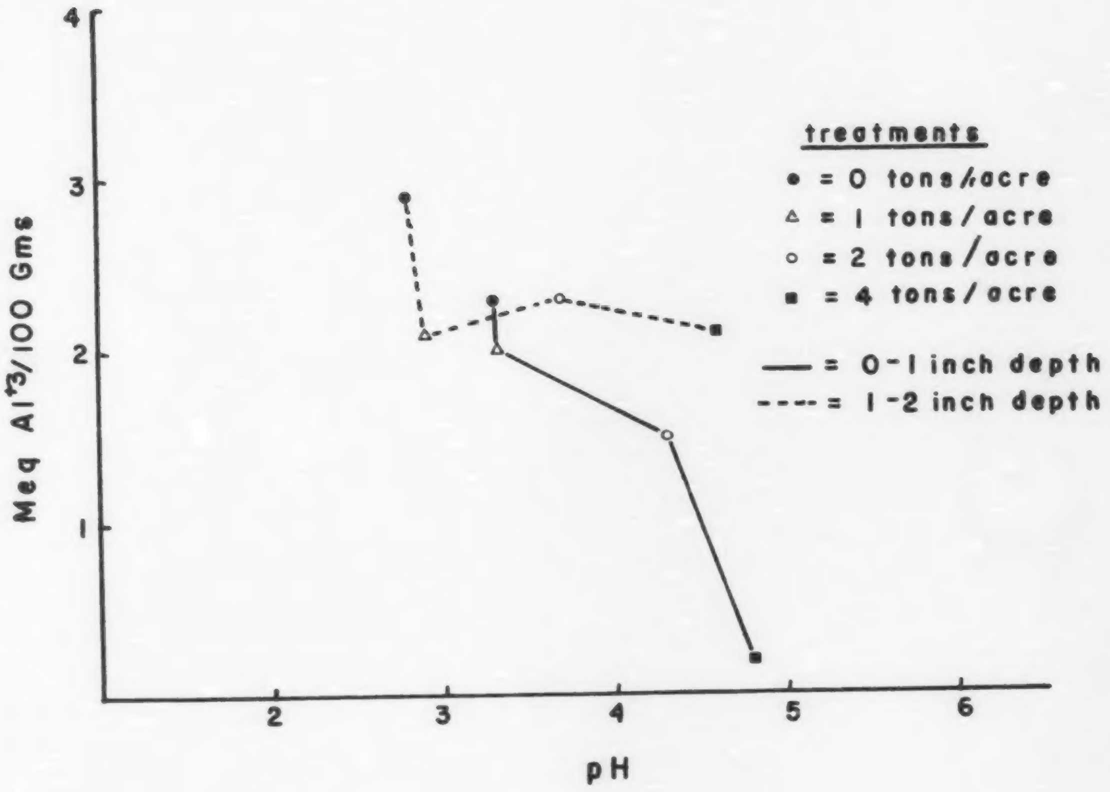


FIGURE 38. pH VERSUS EXCHANGEABLE ALUMINUM AT TWO DEPTHS IN SANDSTONE MINESOIL, SIX MONTHS AFTER SURFACE LIMING WITH STANDARD AGRICULTURAL DOLOMITE.

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SECTION XVI

GLOSSARY

Acid-Base Account - A tabulation of data or graphic presentation of results of analyses for pyritic sulfur content and neutralization potential, from which the maximum potential acidity possible from immediately titratable sources plus sulfur expressed as sulfuric acid equivalent has been calculated, and balanced against total neutralization potential from alkaline carbonates, exchangeable bases, weatherable silicates, or other rock sources capable of neutralizing strong acids.

Calcareous - Containing calcium carbonate.

Carbolith - This name has been coined to cover dark colored sedimentary rocks that will make a black or very dark (Munsell color value of 3 or less) streak or mark on a white streak plate or hard rock like chert. Rocks included under this name include coal, bonecoal, carbon rich muds, and carbon rich shales. An optional name is carbonrock. In general; such rocks will be at least 25% organic matter.

Carbonrock - See carbolith.

Channel sandstone - Sandstone deposited in a stream bed or other channel eroded into the underlying bed.

Chemoautotrophic - Being autotrophic and oxidizing some inorganic compound as a source of energy.

Chert - A rock consisting dominantly of amorphous silica or extremely small (cryptocrystalline) quartz and hard enough to scratch glass or an ordinary knife blade (i.e., hardness of 6.5 to 7.0 on the Moh scale). Flint, Jasper, and other names related to rock color or weathering may be used to identify different kinds of chert.

Clayey - Containing large amounts of clay or having properties similar to those of clay.

Coarse fragments - Rock or mineral particles greater than 2.0 mm. in diameter.

Colluvium - Deposit of rock fragments and soil material accumulated at the base of slopes as a result of gravitational action.

Depositional basin - A segment of the earth's crust which has been downwarped, usually for a considerable time, and into which potential rock-forming materials have been laid down.

Ductile - Capable of considerable deformation, expecially stretching, without breaking.

Efflorescense - Surface encrustation, commonly powdery, produced by evaporation.

Euhedral - Minerals that are bounded by their own crystal faces.

Fines - Material smaller than 2 mm. in effective Stokes diameter.

Fissile - Having a tendency to split along parallel planes, into layers that are less than 2 mm. thick.

Flintclay - A mudrock consisting of high alumina minerals that make it appropriate for use in high temperature firebricks, and which shows conchoidal fracture and other features similar to chert except its hardness which is typical of other mudrocks (hardness 2 to 3 on the Moh scale).

Friable - Easily crumbled, as would be the case with rock that is poorly cemented.

Intercalate - This term is used as a composite noun to include rocks of different kinds that are so intimately interlayered or intercalated that they cannot be sampled or described separately. A sandstone-shale intercalate would be more than 50% sandstone whereas a shale-sandstone intercalate would be more than 50% shale. Other kinds of intercalate rocks would be described by other appropriate rock names.

Interstice - Pore, void.

Interfinger - To grade or pass from one material into another through a series of interlocking or overlapping wedge-shaped layers.

Isomorphous substitution - The replacement of one atom by another of similar size in a crystal lattice without disrupting or changing the crystal structure of the mineral.

Lacustrine - Produced by or belonging to lakes.

Lens - A body of ore or rock thick in the middle and thin at the edges; similar to a double convex lens.

Lime requirement - In an acid soil, the amount of lime ($CaCO_3$) or other base required to neutralize acidity in the range from the initial acid condition to a selected nautral or less acid condition.

Limestone - A sedimentary rock consisting dominantly of calcium or magnesium carbonate, which can be scratched readily with a knife, but not with the fingernail, and which is light colored or white (Munsell color value of 7 or higher) when powdered or streaked on a hard surface. Confirmation of identification may require testing for fizz in dilute (1 to 3 or 1 to 4) hydrochloric acid, although other rocks such as calcareous mudstone may also fizz freely in acid.

Matrix - In a rock in which certain grains are much larger than the others, the grains of the smaller size comprise the matrix.

Minesoil - In accordance with the new soil classification system, *Soil Taxonomy*, Soil Conservation Service, U.S.D.A., soils may be modified or even made by man (see Section V): hence, minesoil is soil made by mining or mining related activity.

Mine spoil - Prior to the present soil classification system, *Soil Taxonomy*, most earthy bodies now called minesoils were designated as mine spoils. The term mine spoil, therefore, is either a synonym for the recently adopted term, minesoil, or it refers to earthy waste material being disrupted or moved during mining or mining related activity.

Mottling - Spots or blotches of different color or shades of color interspersed with the dominant color.

Mudrock - A broad term for sedimentary rock dominated by silt and (or) clay sized particles, without restrictions on mineralogy. This rock type may contain as much as 50% sand if properties are judged to be dominated by silt and (or) clay. If sand (grit) is noticeable by observation or feel, the rock may be called sandy mudrock. Mudstone is considered a satisfactory synonym for mudrock, but some authorities may exclude all fissile (prominently layered) sediments from their definition of mudstone. Mudrocks may contain any proportion of carbonate so long as particles are dominantly silt and (or) clay when rubbed in water.

Mudstone - See mudrock.

Nodular - Containing at least 10% by volume of rounded bodies of rock that are generally somewhat more cohesive or harder than the enclosing sediment or rock matrix.

Nodule - More or less rounded body generally somewhat harder than the enclosing sediment or rock matrix.

Overburden - Earth material, consolidated or unconsolidated, that overlies a deposit of useful materials, ores, or coal, especially those deposits that are mined from the surface by open cuts.

Ped - A unit of soil structure such as an aggregate, crumb, block, prism, or granule, formed by natural processes.

Phase, soil - A subdivision of a soil type or other unit of classification having characteristics that affect the use and management of the soil but which do not vary sufficiently to differentiate it as a seperate type.

pH-dependent charge - That portion of the total charge of the soil (clay) particles which is affected by, and varies with, changes in pH.

Sandstone - A sedimentary rock consisting dominantly of sand-sized, that is visible grains that feel gritty when rubbed in water. Silt and clay combined may total as much as 50% of the total rock weight. When more than 15% of a sandstone consists of particles finer than sand, the rock may be called a muddy sandstone, silty sandstone, clayer sandstone, argillaceous sandstone, or other kind of descriptive name.

Schlick - A mass of body of silt and (or) clay that would be called Schlickstone except that it is very soft when wet (hardness about 1.0) and may not fit popular concepts of stone or rock. From the standpoint of soil structure, Schlick is massive, although it may show some stratification.

Shale - A mudrock that appears prominently thin-layered or fissile. Shale often is more resistant to physical breakdown in water than non-fissile mudrock and usually is harder to scratch. Some indurated shale cannot be scratched with the fingernail.

Sinuous - Of a serpentine or wavy form.

Soil separates - Mineral particles, 2.0 mm. in equivalent Stokes diameter, ranging between specified size limit.

sand: 2.0 - 0.05 mm.
silt: 0.05 - .002 mm.
clay: less than 0.002 mm.

Stringer - A narrow vein or irregular filament of mineral traversing of rock mass of different material, or a thin layer of coal at the top of a bed, separating in places from the main coal by material similar to that comprising the roof.

Topsoil - Presumed fertile soil material used as top dressing.

Toxic materials - Any rock or earth material having a pH of less than 4.0 or a net potential deficiency of 5.0 tons of calcium carbonate equivalent or more per thousand tons of material as determined by the acid-base accounting method.

Weathering - All physical and chemical changes produced in rocks, at or near the earth's surface, by atmospheric agents.

SECTION XVII

APPENDICES

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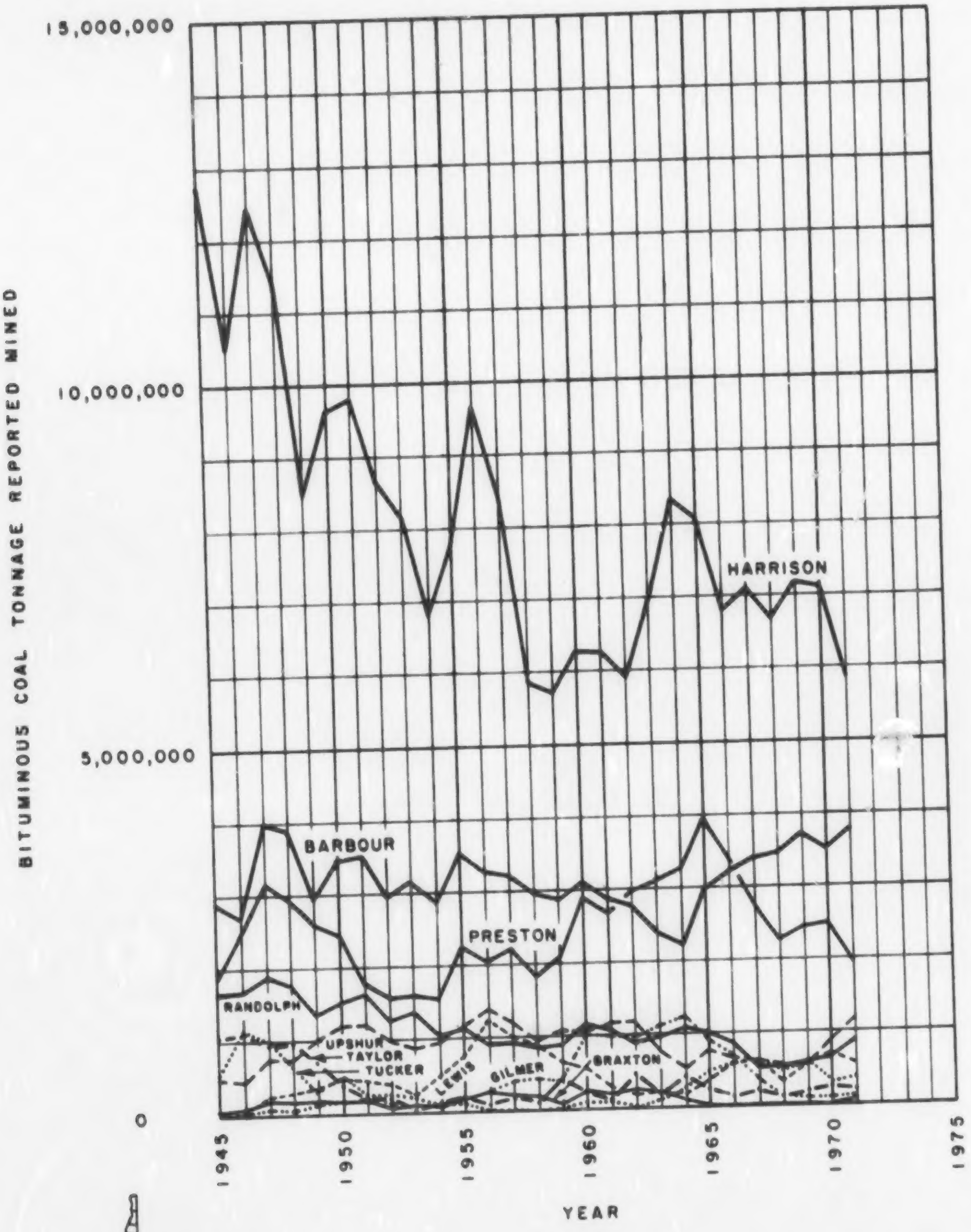
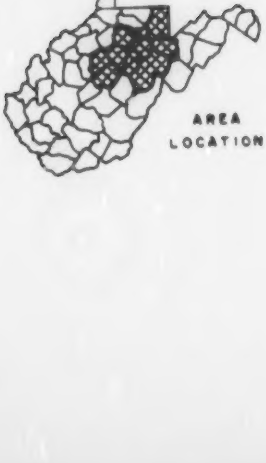
APPENDIX A

Table 66

Reserves and total production of coal in Braxton, Gilmer, Lewis, Harrison, Upshur, Barbour, Taylor, Randolph, Tucker and Preston counties, West Virginia.

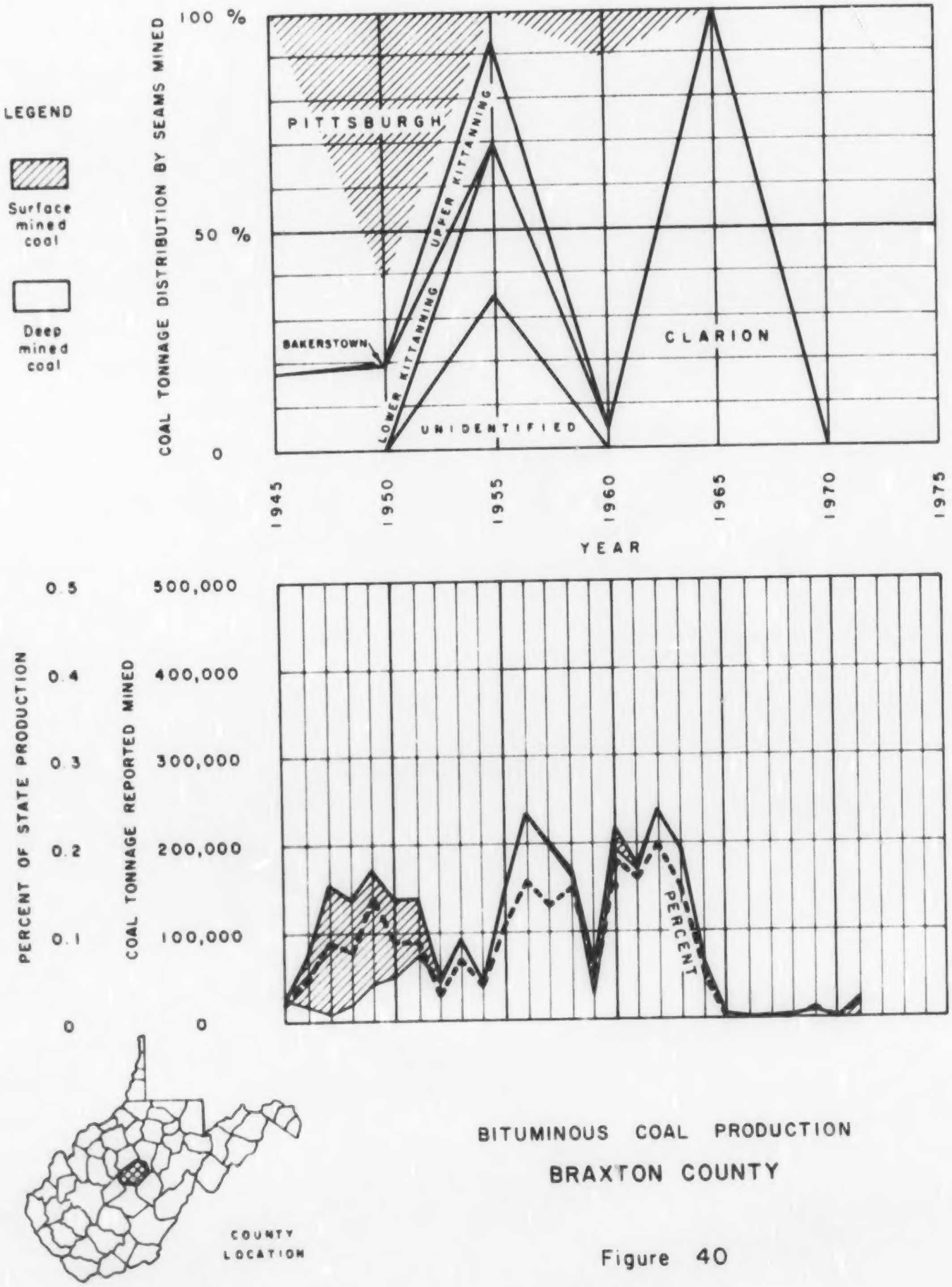
County	Original Reserves	Estimated Recoverable Reserves	Reported Production (1883--1970)
	(thousands of tons)		
Braxton	2,323,333	1,152,511	9,154
Gilmer	1,019,245	497,045	12,577
Lewis	2,776,037	1,375,228	12,790
Harrison	2,172,731	653,381	432,984
Upshur	3,554,552	1,743,123	34,153
Barbour	3,585,619	1,648,523	144,287
Taylor	1,327,767	616,098	47,785
Randolph	4,183,644	2,448,282	61,928
Tucker	486,964	186,289	57,193
Preston	3,212,324	1,485,468	120,694





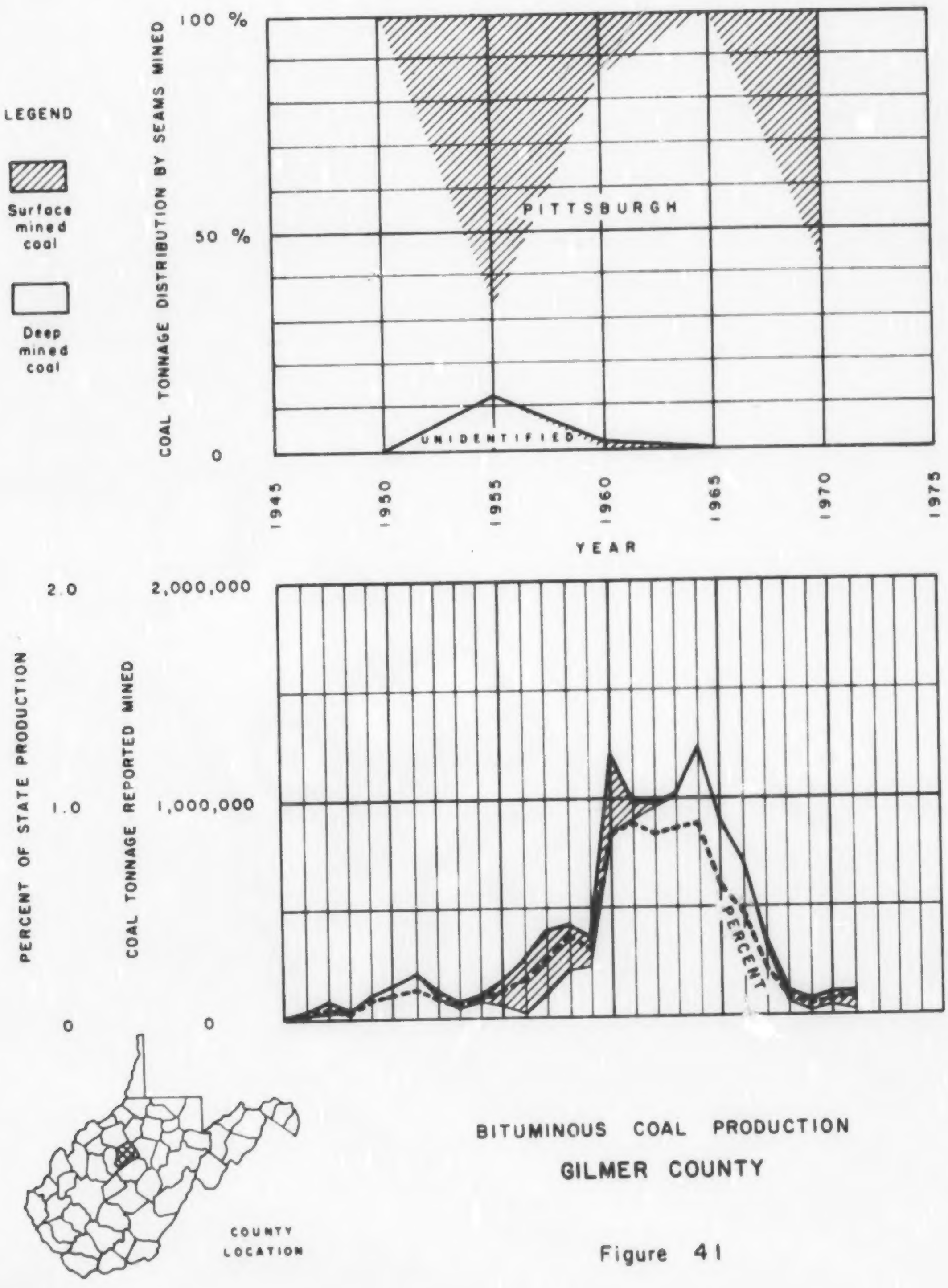
COAL PRODUCTION OF COUNTIES
IN AREA OF STUDY

Figure 39



BITUMINOUS COAL PRODUCTION
BRAXTON COUNTY

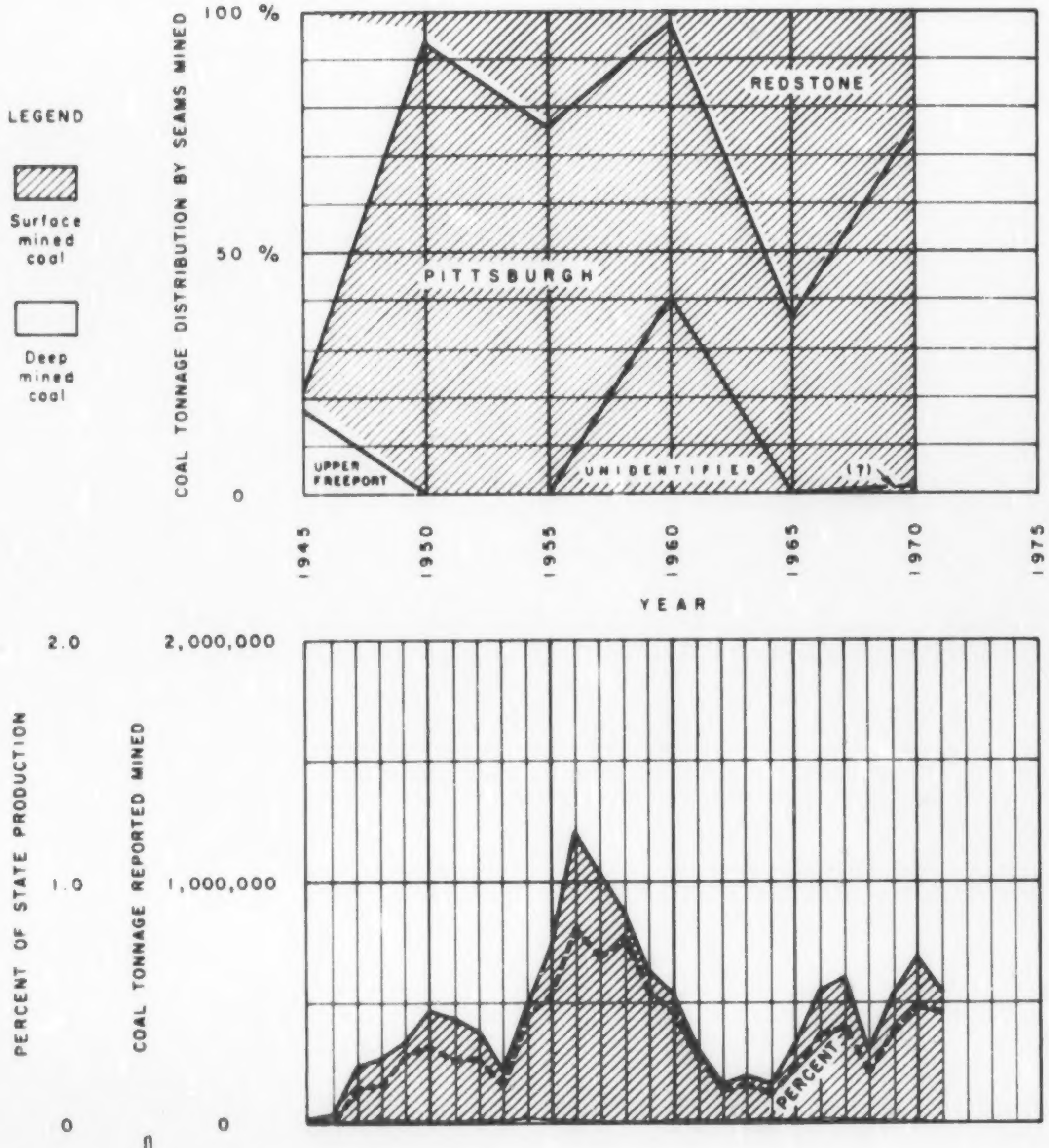
Figure 40

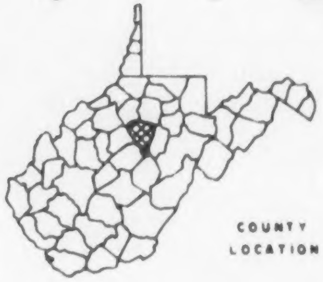


BITUMINOUS COAL PRODUCTION

GILMER COUNTY

Figure 41

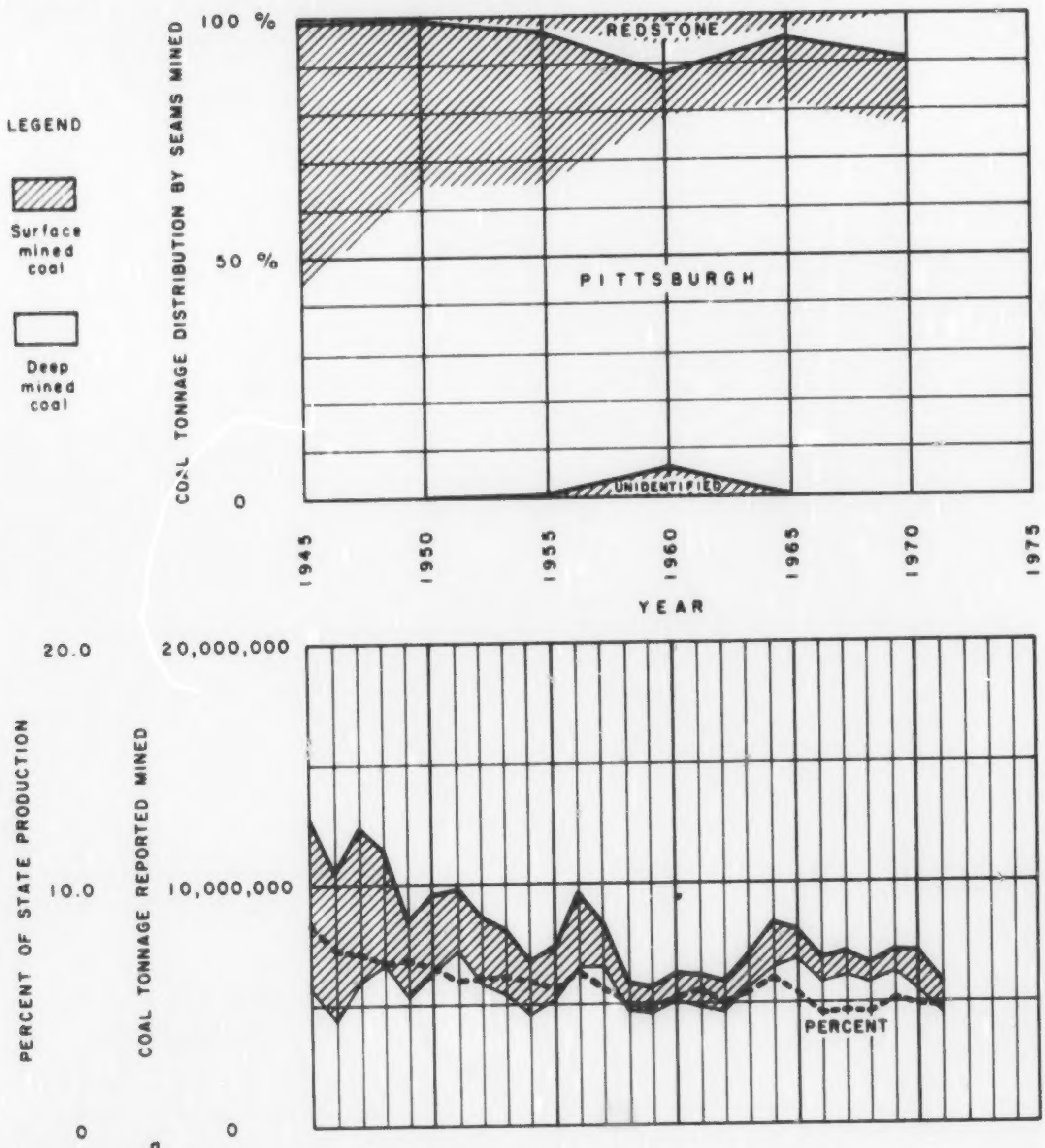


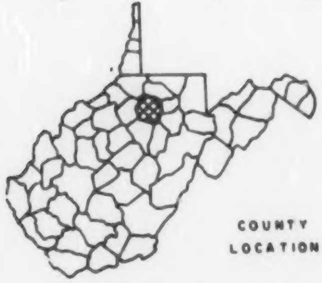


BITUMINOUS COAL PRODUCTION

LEWIS COUNTY

Figure 42

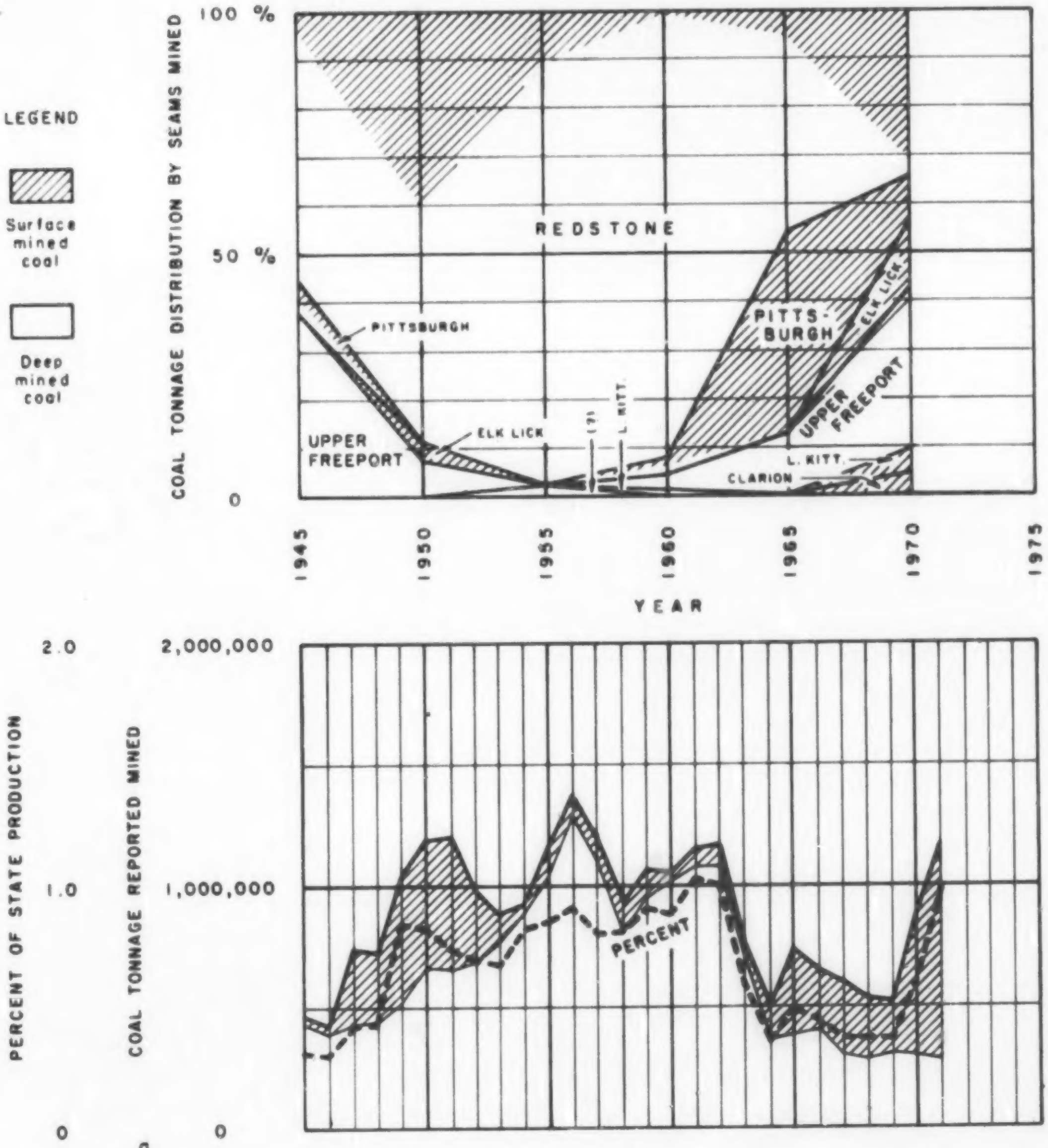


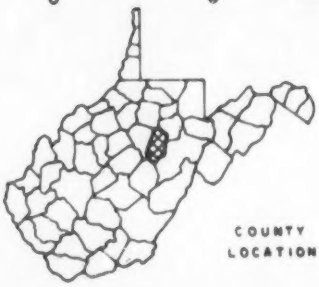


BITUMINOUS COAL PRODUCTION

HARRISON COUNTY

Figure 43

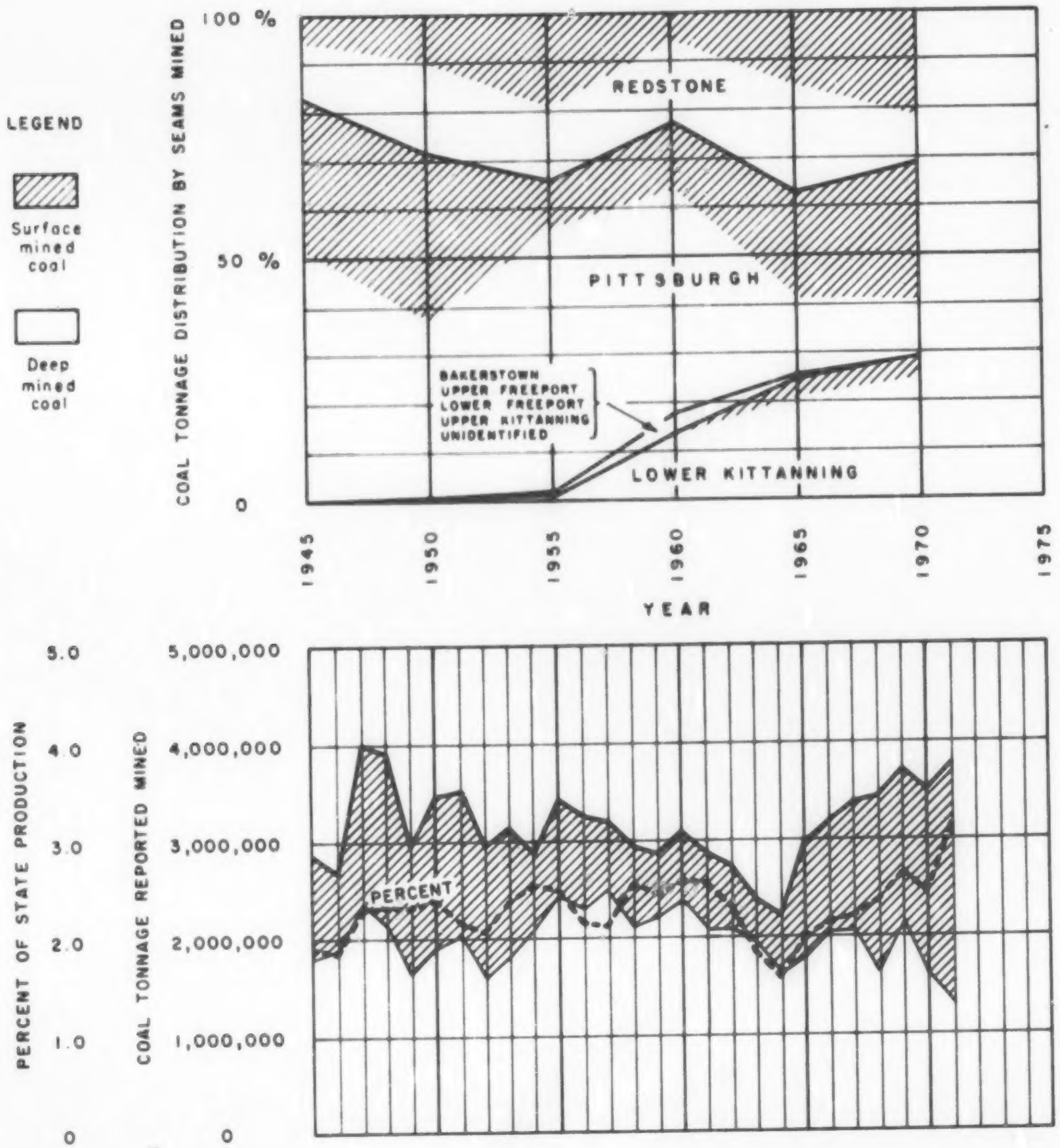


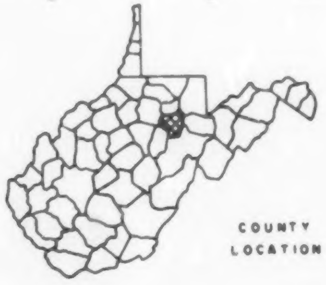


BITUMINOUS COAL PRODUCTION

UPSHUR COUNTY

Figure 44

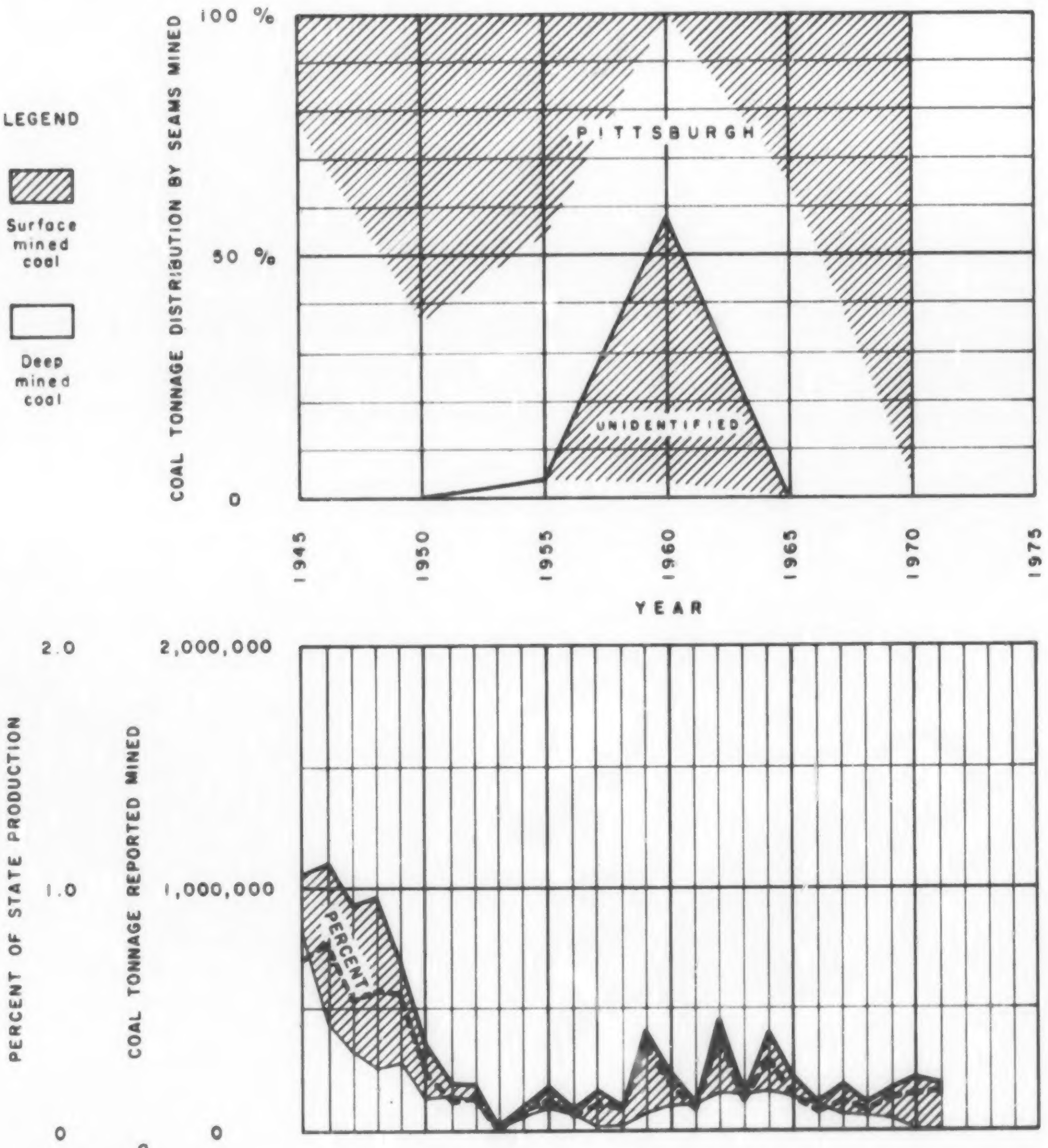


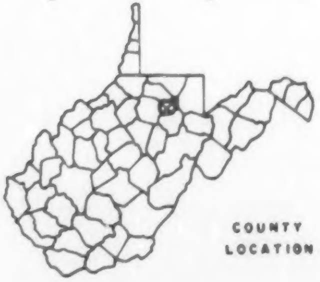


BITUMINOUS COAL PRODUCTION

BARBOUR COUNTY

Figure 45

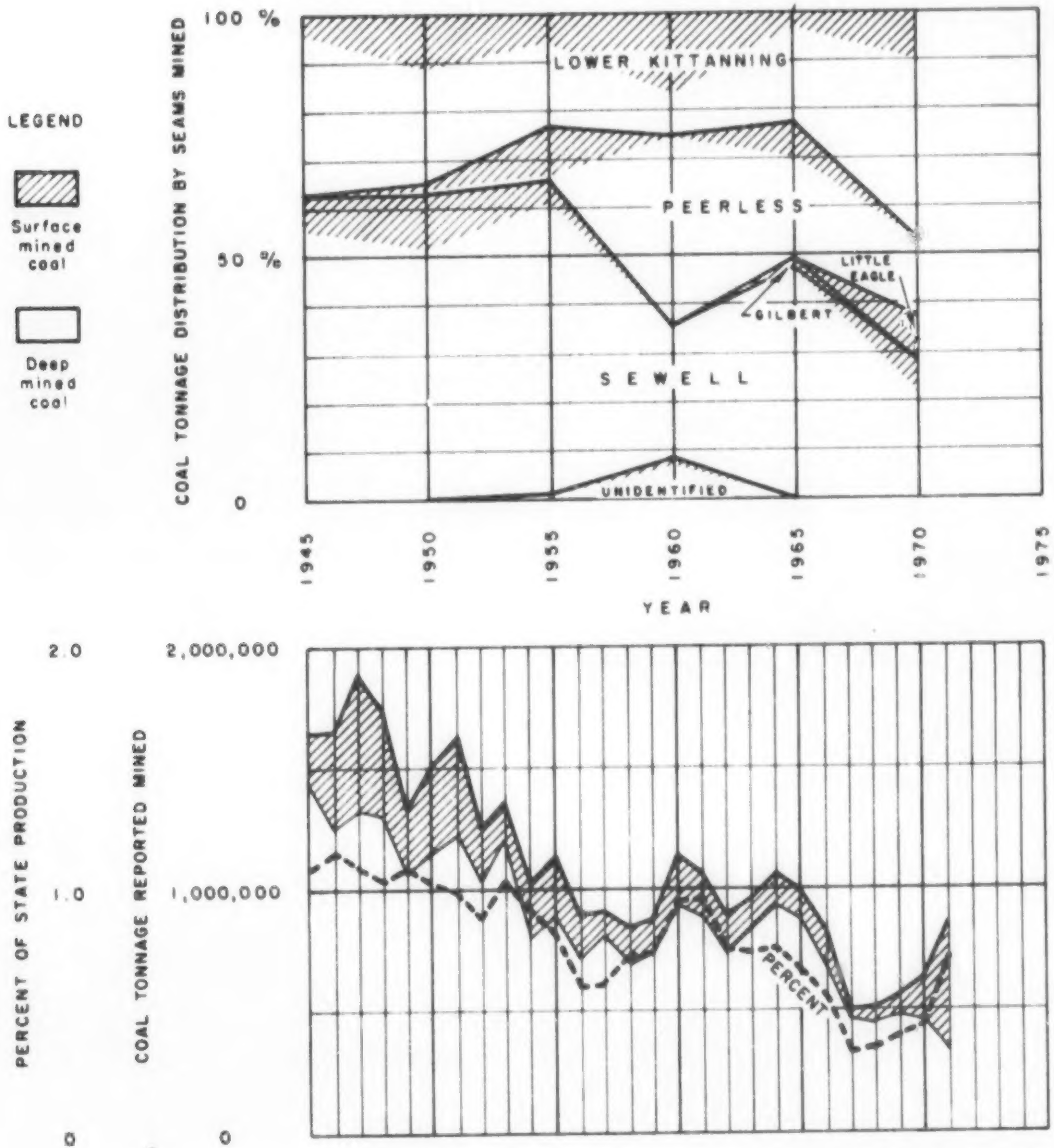


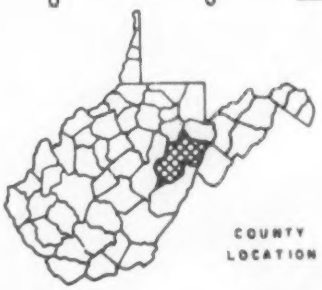


BITUMINOUS COAL PRODUCTION

TAYLOR COUNTY

Figure 46

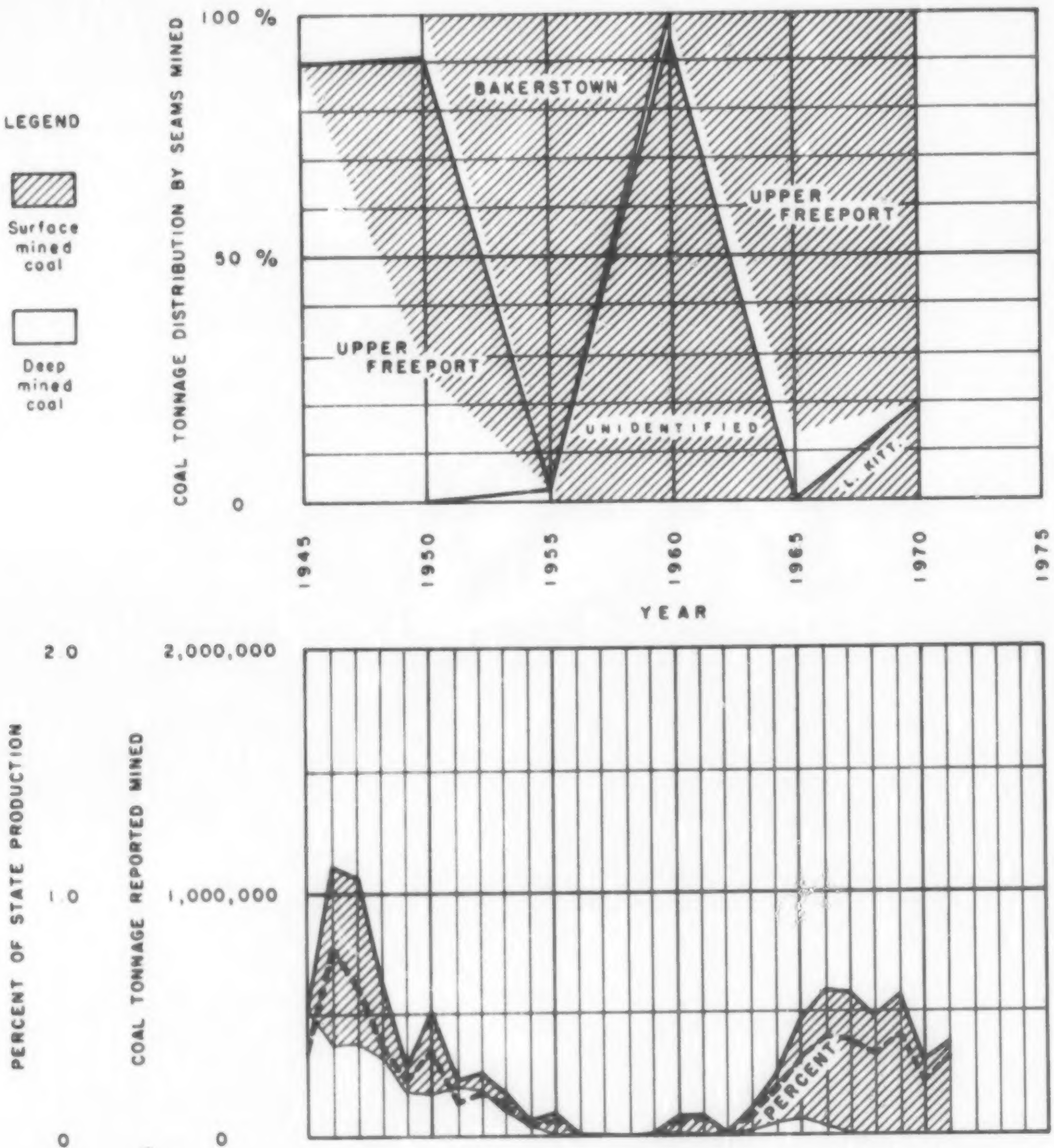


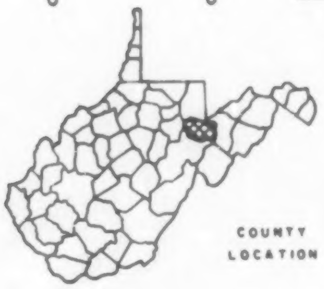


BITUMINOUS COAL PRODUCTION

RANDOLPH COUNTY

Figure 47

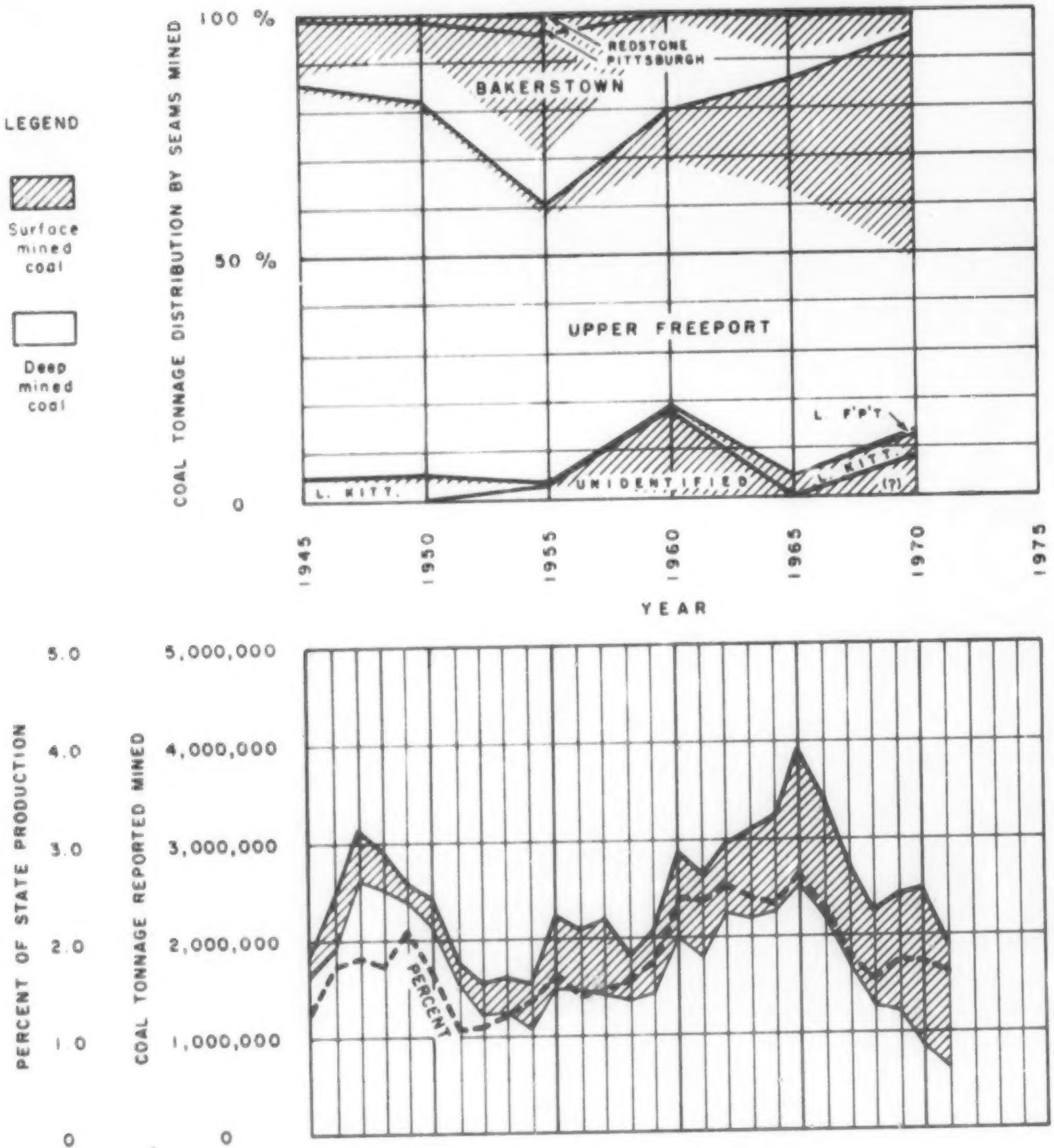


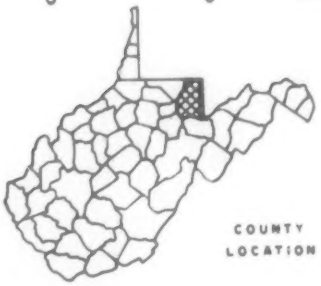


BITUMINOUS COAL PRODUCTION

TUCKER COUNTY

Figure 48





BITUMINOUS COAL PRODUCTION

PRESTON COUNTY

Figure 49

APPENDIX B

Table 67. AVERAGE ANALYSES[a] OF ASH AND SULFUR OF PITTSBURGH AND REDSTONE COALS IN AN AREA OF 880 SQUARE MILES BISSECTED BY GEOLOGIC CROSS SECTION A-A'.

County	Name of Coal	No. of Analyses	Average Thickness in ft.: Mining Section	Partings	Percent Ash	Sulfur	Condition of Sample
Roane[b]	Pittsburgh	4	3-6 1/4	1-7/8	6.92	2.01	A.R.
Calhoun[b]	Pittsburgh	3	3-0 1/4	0-1/4	6.97	3.41	A.R.
Gilmer	Pittsburgh	18	5-11	0-0 3/4	6.57	2.32	A.R.
Braxton[b]	Pittsburgh	7	5-9 1/8	0-2	6.31	2.05	A.R.
Lewis	Redstone	14	4-4 1/2	0-2 1/4	7.06	2.77	A.R.
	Pittsburgh	3	4-5 1/4	0-1	6.24	2.52	A.R.
Harrison	Redstone	6	6-0	0-1	7.65	1.80	A.R.
	Pittsburgh	2	5-1 1/7	0-0 13/16	6.15	4.15	A.R.
Upshur	Redstone	14	4-10 1/4	------	6.73	1.99	A.R.
	Pittsburgh	1	7-0	0-8	6.55	3.08	A.R.
Barbour	Redstone	4	5-3 5/8	------	5.43	1.96	A.R.
	Pittsburgh	7	7-6 1/2	0-5 1/2	6.47	2.80	A.R.

Table 67 (continued)

County	Name of Coal	No. of Analyses	Average Thickness in ft.: Mining Section	Partings	Percent Ash	Sulfur	Condition of Sample
Taylor	Pittsburgh	11	6-11 1/2	0-1 7/8	6.81	2.46	A.R.
Gilmer[b]	Pittsburgh	4	9-8 1/4	0-2	7.05	2.12	A.R.

[a] Above data taken from the following reports:

Hennen, R. V., 1911, p. 215-223.
_____________, 1912, p. 207, 209, 211, 571, 572, 615, 633, 639, 640.

Hennen, R. V. and D. B. Reger, 1913, p. 703-709, 742, 743.

Reger, D. B., 1916, p. 515, 516, 518, 521, 524, 526-528, 530, 532, 533, 536, 540, 541, 544, 546-556, 593, 594.
_____________, 1917, p. 486, 487, 488, 502, 503, 505, 507, 775.

Reger, D. B. and D. D. Teets, Jr., 1918, p. 444, 446-457, 461-463, 469-471, 474-476, 738.

[b] Outside area of investigation.

Table 68. AVERAGE ANALYSES[a] OF ASH AND SULFUR OF LOWER, MIDDLE AND UPPER KITTANNING, LOWER AND UPPER FREEPORT AND BAKERSTOWN COALS IN AN AREA OF OVER 500 SQUARE MILES BISSECTED BY GEOLOGIC CROSS SECTION B-B'.

County	Name of Coal	No. of Analyses	Average Thickness in ft.:		Percent		Condition of Sample
			Mining Section (includes bone & shale)	Partings	Ash	Sulfur	
Randolph	Middle and Lower Kittanning	8	7-8 3/4	1-2 2/3	10.74	1.88	A.R.
	Clarion	1	9-9	3-1	8.44	1.86	A.R.
Upshur	Lower Freeport	1	3-1		12.39	4.78	A.R.
	Middle Kittanning	3	4-0	0-8 2/3	9.78	3.82	A.R.
Barbour	Bakerstown	4	4-1	1-2	7.54	2.42	A.R.
	Upper Freeport	7	4-8	1-2	11.97	3.51	A.R.
	Upper Kittanning	5	3-10	0-6	11.16	3.08	A.R.
	Lower Kittanning	17	6-0	1-1	10.56	1.99	A.R.
Preston	Bakerstown	4	3-9 3/4	0-9 3/4	6.38	1.65	A.R.
	Upper Freeport	42	5-10	1-2	8.40	1.69	A.R.

Table 68 (continued)

County	Name of Coal	No. of Analyses	Average Thickness in ft.: Mining Section (includes bone & shale)	Partings	Percent Ash	Percent Sulfur	Condition of Sample
Preston	Lower Freeport	2	3-10	2-4	15.43	3.52	A.R.
	Upper Kittanning	7	4-1	0-5 1/3	10.07	2.37	A.R.
	Lower Kittanning	17	6-5	1-10	8.92	1.36	A.R.

[a] Data from the following reports:

Hennen, R.V. and D. B. Reger, 1914, p. 137, 139, 160, 163, 271, 273, 279-283, 287-291, 295-298, 301-304, 306, 309, 314-317, 319, 320, 327, 329, 332-334, 340, 342, 343-345, 347, 364-367.

Reger, D. B. and D. D. Teets, Jr., 1918, p. 247, 492, 495, 497, 513-515, 518, 519, 525, 526, 532, 534, 535, 537, 539, 554, 559, 560, 563, 568, 570-572, 574, 575, 578, 588, 589, 592, 595, 596, 598, 607, 611, 616, 624-626, 630, 631, 633, 635, 636, 647, 739-741.

APPENDIX C

SECTIONS AND CORES
ON
CROSS SECTION A-A'

1. Glenville Section, Glenville District, Gilmer County, West Virginia (Reger, D.B., 1916, Lewis and Gilmer counties, West Virginia: West Virginia Geol. Survey p. 85.)
2. Cedarville Section, Center District, Gilmer County, West Virginia (Reger, D.B., 1916, Lewis and Gilmer counties, West Virginia: West Virginia Geol. Survey p. 94.)
3. Vadis Section, Freemans Creek District, Lewis County, West Virginia (Reger, D. B., 1916, Lewis and Gilmer counties, West Virginia: West Virginia Geol. Survey p. 60.)
4. Hurst Section, Freeman Creek District and J.C. Marsh Core Test (WVGS Number 280) Lewis County, West Virginia (Reger, D.B., 1916, Lewis and Gilmer counties, West Virginia: West Virginia Geol. Survey p. 56-58.)
5. Alum Bridge Section, Freemans Creek District, Lewis County, West Virginia (Reger, D.B., 1916, Lewis and Gilmer counties, West Virginia: West Virginia Geol. Survey p. 60, 61.)
6. Camden Section, Freemans Creek District, Lewis County, West Virginia (Reger, D.B., 1916, Lewis and Gilmer counties, West Virginia: West Virginia Geol. Survey p. 58, 59.)
7. Town Run Section, Courthouse District, Lewis County, West Virginia (Reger, D.B., 1916, Lewis and Gilmer counties, West Virginia: West Virginia Geol. Survey p. 127.)
8. Interstate 79 and U.S. Route 33 Section, Hackers Creek District, Lewis County, West Virginia.
9. Hyre Brake No. 1 Coal Test Boring (WVGS Number 82, Buckhannon District, Upshur County, West Virginia (Reger, D.B., 1916, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey p. 415.)
10. Groundhog Hollow Section, Warren District, Upshur County, West Virginia (Reger, D.B., 1916, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey p. 119, 120.)

11. Ruraldale Section, Warren District, Upshur County, West Virginia (Reger, D.B., 1916, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey p. 120, 121.)

12. B.M. Core Record No. 1, Warren District, Upshur County, West Virginia, Bethlehem Mines Corporation, Century, West Virginia.

13. Pecks Run Section, Warren District, Upshur County, West Virginia (Reger, D.B., 1916, Barbour and Upshur counties and western portion of Randloph County, West Virginia: West Virginia Geol. Survey p. 121.)

14. Dick Drain of Gnatty Creek Section, Union District, Barbour County, West Virginia.

15. Arnolds Creek Section, Elk District, Barbour County.

16. Brushy Fork Section, Simpson District, Harrison County, West Virginia (Hennen, R.V., 1912, Doddridge and Harrison counties, West Virginia: West Virginia Geol. Survey p. 208.)

17. Divide Section between Taylor Run and Pleasant Creek, Pleasant District, Barbour County, West Virginia.

SECTIONS AND CORES
ON
CROSS SECTION B-B'

1. Measured section in LaRosa Surface Mine, Whitman Flats, Middle Fork District, Randolph County, West Virginia.

2. U.S.G.S. Core Record No. 32, Roaring Creek District, Randolph County, West Virginia. (Geological Survey Water Resources Division U.S. Department of Interior Acid Mine Demonstration Project No. W.Va. -7-0.)

3. U.S.G.S. Core Record No. 4, Roaring Creek District, Randolph County, West Virginia. (Geological Survey Water Resources Division U.S. Department of Interior Acid Mine Demonstration Project No. W.Va. -7-0.)

4. U.S.G.S. Core Record No. 3, Roaring Creek District, Randolph County, West Virginia. (Geological Survey Water Resources Division, U.S. Department of Interior Acid Mine Demonstration Project No. W.Va. -7-0.)

5. U.S.G.S Core Record No. 9, Roaring Creek District, Randolph County, West Virginia. (Geological Survey Water Resources Division, U.S. Department of Interior Acid Mine Demonstration Project No. W.Va. -7-0.)

6. Davis Coal and Coke Company No. 5 Coal Test Boring (WVGS Number 52), Barbour County, West Virginia, (Reger, D.B., 1918, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey, p. 406.)

7. Flora Section, Glade District and Isaac Coonts Coal Test Record (WVGS Number 39), Barbour County, West Virginia (Reger, D.B., 1918, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey., p. 108-109.)

8. Meadowville Section, Glade District and Nelson H. Harris Coal Test Record (WVGS Number 37), Barbour County, West Virginia (Reger, D.B., 1918, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey, p. 107-108.)

9. Nestorville Section, Cove District and Lewis Auvill Coal Test (WVGS Number 33), Barbour County, West Virginia (Reger, D.B.,

1918. Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey, p. 104-105.)

10. Allie Rosier Coal Test (WVGS Number 30), Cole District, Barbour County, West Virginia (Reger, D.B., 1918, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey, p. 403-404.)

11. Colebank Section, Cove District and James Lindsey Coal Test Record (WVGS Number 29), Barbour County, West Virginia (Reger, D.B., 1918, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey, p. 101-103.)

12. Marcellus Knotts Core Test (WVGS Number 97A), Reno District, Preston County, West Virginia (Hennen, R.V. and Reger, D.B., 1914, Preston County, West Virginia: West Virginia Geol. Survey p. 256.)

13. Austen Coal and Coke Company Core Test No. 4 (WVGS Number 88) Reno District, Preston County, West Virginia (Hennen, R.V., and Reger, D.B., 1914, Preston County, West Virginia: West Virginia Geol. Survey p. 257.)

14. Rowlesburg Section, Reno District, Preston County, West Virginia (Hennen, R.V. and Reger, D.B., 1914, Preston County, West Virginia: West Virginia Geol. Survey p. 97-98.)

15. Core Record No. VH 101, Pleasant District, Preston County, West Virginia.

16. Core Records No. VH 102 and FP 19 (Kingwood Mining Co.) Pleasant District, Preston County, West Virginia.

17. Core Record No. FP 17 (Kingwood Mining Co.) Pleasant District, Preston County, West Virginia.

18. Core Record No. FP 25 (Kingwood Mining Co.) Pleasant District, Preston County, West Virginia.

19. Brandonville Section, Grant District and Hudro-Electric Company of West Virginia Core Test No. 2 (WVGS Number 6) Preston County, West Virginia (Hennen, R.V. and Reger, D.B., 1914, Preston County, West Virginia: West Virginia Geol. Survey p. 80-81.)

SECTIONS AND CORES
ON
CROSS SECTION C-C'

1. Hall, Union District, Barbour County, West Virginia (Reger, D. B., 1918, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey, p. 94.

2. L. R. No. 1 Coal Test Boring, north of Lick Shoals Run, Union District, Barbour County, West Virginia.

3. A. V. Wilmoth No. 5 Coal Test Boring (WVGS Number 64A), Barbour County, West Virginia (Reger, D. B., 1918 Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey p. 411.

4. Belington Section, Barker District and Blackman Wilmoth No. 3 Coal Test Record (WVGS Number 70) Barbour County West Virginia (Reger, D. B., 1918, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey, p. 112-113).

5. Junior Section, Valley District and Cora Wilson (William Bonar) No. 1 Coal Test (WVGS Number 69) Barbour County, West Virginia (Reger, D. B., 1918, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey, p. 115).

6. Davis Coal and Coke Company No. 5 Coal Test Boring (WVGS Number 52), Barbour County, West Virginia, (Reger, D. B., 1918, Barbour and Upshur counties and western portion of Randolph County, West Virginia: West Virginia Geol. Survey p. 406.

SECTIONS AND CORES
ON
CROSS SECTION D-D'

1. Fred Wotring Bore Hole No. 1 (WVGS Number 103), Preston County, West Virginia (Hennen, R. V. and Reger, D. B., 1914, Preston County, West Virginia: West Virginia Geol. Survey, p. 259).

2. Wilson Bore Hole No. 3 (WVGS Number 104), Garrett County, Maryland (Hennen, R. V. and Reger, D. B., 1914, Preston County, West Virginia: West Virginia Geol. Survey, p. 259-260).

3. Davis Coal and Coke Company No. 50 Coal Test Boring (WVGS Number 41) Tucker County, West Virginia (Reger, D. B., 1923, Tucker County, West Virginia: West Virginia Geol. Survey p. 337-338).

4. Davis Coal and Coke Company No. 52 Coal Test Boring (WVGS Number 63), Tucker County, West Virginia (Reger, D. B., 1923, Tucker County, West Virginia, West Virginia Geol. Survey p. 351-352).

5. Thomas Section, Fairfax District and Davis Coal and Coke Company No. 11 Coal Test Boring (WVGS Number 15) Tucker County, West Virginia (Reger, D. B., 1923, Tucker County, West Virginia: West Virginia Geol. Survey p. 128-129).

6. Douglas Section, Fairfax District, Tucker County, West Virginia (Reger, D. B., 1923, Tucker County, West Virginia: West Virginia Geol. Survey p. 125-127).

7. Davis Coal and Coke Company No. 121 (WVGS Number 65) and Mining Section Upper Freeport coal (WVGS Number 64), Davis District, West Virginia (Reger, D. B., 1925, Tucker County, West Virginia: West Virginia Geol. Survey p. 353-354).

8. Stonecoal Run of Red Creek Section, Dry Fork District and Robert Bridges Estate No. 2 Coal Test Boring (WVGS Number 81), Tucker County, West Virginia (Reger, D. B., 1923, Tucker County, West Virginia, West Virginia Geol. Survey p. 141-142).

APPENDIX D

Minesoil Profile Description

Site 1-1

DATE: June, 1971

LOCATION: Appalachian Coal Company, East of Brandonville, Preston County, Site is located 1 1/16 miles east and 1 5/16 miles north of Shady Grove Church. Lower Kittanning coal.

DESCRIBED AND SAMPLED BY: Sencindiver and Sturm

VEGETATION: Ryegrass, alsike clover. One year old spoil.

Horizons:

1	0-1"	--Dull yellowish brown (10YR 4/3 & 5/3) loam to clay loam; medium, moderate granular structure; friable; many roots; pH 6.5-7.0; clear boundary.
2	1-10"	--Dull yellowish brown (10YR 4/3) and bright yellowish brown (10YR 6/6) loam to clay loam; weak subangular blocky structure; friable to firm; common, distinct parent material mottles; 5-10% coarse fragments; pH 6.0; abrupt, irregular boundary.
3	10-22"	--Dark gray (N 3/0) layered shale; 60% coarse material; few, fine roots; roots go down through the shale layer.
4	22-34"	--Dark gray (N 3/0) shale fragments; 75% coarse material; common, fine roots; pH 4.5.
5	34"+	--Dark gray (N 3/0) hard shale, disordered.

APPENDIX D

Minesoil Profile Description

Site 1-2

DATE: June, 1971

LOCATION: Appalachian Coal Company, East of Brandonville, Preston County. Site is located 180 feet northwest of pit 1-1. Lower Kittanning coal.

DESCRIBED AND SAMPLED BY: Sencindiver and Sturm

VEGETATION: Ryegrass, timothy, alsike clover, ox-eye daisy. One year old spoil.

Horizons:

1 0-1" --Dull yellowish brown (10YR 4/3) loam; no mottling; friable; many roots; 30% coarse fragments; pH 7.0; abrupt; wavy boundary.

2 1-9" —Dull yellowish brown (10YR 4/3) loam; common distinct parent material mottles; friable to firm; 45% coarse fragments; many roots; abrupt, irregular boundary.

3 9-36"+ —Black and brown shale; common roots; 75% coarse fragments (shale) with 50% greater than 3".

APPENDIX D

Minesoil Profile Description

Site 1-3

DATE: June, 1971

LOCATION: Appalachian Coal Company, East of Brandonville, Preston County. Site is located directly north of pit 1-2 approximately 50 feet north of county road. Lower Kittanning coal.

DESCRIBED AND SAMPLED BY: Sencindiver and Sturm

VEGETATION: Birdsfoot trefoil, timothy, alsike clover, oxeye daisy. Revegetated 4 or 5 years.

Horizons:

1 0-1" --Dull yellowish brown (10YR 5/3 and 5/4) loam to sandy loam; weak granular structure; friable; 55% coarse fragments; many roots; pH 7.0; abrupt, wavy boundary.

2 1-7" --Dull yellowish brown (10YR 5/4) clay loam; common, distinct bright yellowish brown (10YR 6/8) mottles; massive to weak, granular structure with some platelike structure; friable to firm; 55% coarse fragments, black and brown shales; many roots; pH 5.0-5.5; abrupt, irregular boundary.

3 7-24" --Dull yellowish brown (10YR 5/4) loam; common, distinct bright yellowish brown (10YR 6/8) mottles; massive structure; friable to firm; 75% coarse fragments of black brown shale with 25% greater than 3"; some discontinuous layers of shale; common roots; pH 4.5; clear, wavy boundary.

4 24-35" --Dull yellowish brown (10YR 4/3) and brown (10YR 4/4) loam; common, distinct bright yellowish brown (10YR 6/8) mottles; massive and shale controlled structure; friable to firm; 80%

coarse fragments of black and brown shale; few roots; abrupt, smooth boundary.

5 35-37"+ —Dark gray (N 3/0) shales with only 10-15% fine material with a color of bright yellowish brown (10YR 6/8); friable to firm of fines; no roots; pH 4.5.

Notes: The digging was easier from 24" to the bottom of the pit than it was in the top 24". Shale seemed to be somewhat layered in 3rd horizon but discontinuous. However, as the profile went deeper the shales were more broken up and at all angles.

APPENDIX D

Minesoil Profile Description

Site 2-1

DATE: July 9, 1971

LOCATION: Appalachian Coal Company, South of Brandonville, Preston County. Site is located on Kelly Farm 3 miles south of Shady Grove Church. Upper Freeport coal.

DESCRIBED AND SAMPLED BY: Sencindiver and Sturm.

VEGETATION: Birdsfoot trefoil, white clover, timothy, buckhorn plantain. 12 year old spoil.

Horizons:

1	0-2"	--Dark brown (10YR 3/3) loam; weak granular structure; friable; many roots; clear, wavy boundary.
2	2-35"	--Bright yellowish brown (10YR 6/8), brown (7.5YR 4/3) and dull yellowish brown (10YR 5/3 and 4/3); firm; 75% coarse fragments, 70% shale and 5% sandstone; mixed black and brown shales; common roots; clear, wavy boundary.
3	35-39"+	--Colors same as above horizon; 25-35% coarse fragments (no sandstone); friable to firm; few roots, some trefoil tap roots extend to bottom of pit.

Notes:

depth	pH
1"	6.0
21"	6.0
36"	6.0

Well-drained.

APPENDIX D

Minesoil Profile Description

Site 2-2

DATE: July 13, 1971

LOCATION: Site is 90 feet southwest of site 2-1. Upper Freeport coal.

DESCRIBED AND SAMPLED BY: Sencindiver, Grube, and Smith.

VEGETATION: Birdsfoot trefoil, white clover, canada thistle. 12 year old spoil.

Horizons:

1	0-2"	--Dark brown to brownish black (10YR 3/2.5); weak, fine granular; friable; 50% coarse fragments; clear boundary.
2	2-10"	--Yellow orange (10YR 7/8) and brownish black (10YR 3/2); many roots; 60% coarse fragments; 25-35% of horizon is sandstone; black and bright reddish brown (5YR 5/8) thin bedded and randomly oriented shales; black and brown concretionary material.
3	10-30"	--Thin bedded shales disordered; firm; 25-30% sandstone; common roots; pressure faces evident on sandstone.

Notes: Variability of colors with black dominant; browns, grays and lighter colors in sandstone; shales predominantly black interior. Probably enough sandstone in this pit to classify as Typic (mixed). Mottling associated with different rock types.

depth	pH
Surface	8.0
10"	5.0
18"	4.5
28"	5.0

APPENDIX D

Minesoil Profile Description

Site 3-1

DATE: July 15, 1971

LOCATION: Site is located approximately 50 feet from site 3-2.

DESCRIBED AND SAMPLED BY: Sencindiver, Grube, Smith, and Singh

VEGETATION: No vegetation at pit site. 20-25 year old spoil.

Horizons:

1	0-2"	—Brownish black (10YR 3/1); weak granular structure; very friable; 40% coarse fragments of shale (> 2mm). pH 4.0.
2	2-41"	--Bright yellowish brown (10YR 6/8), brownish gray (10YR 6/1) and dull yellow orange (10YR 6/4) silty clay loam with some pockets of clay; low chroma colors seem to follow root channels; approximately 40% of color is high chroma; massive; firm; 55% coarse fragments; shales disordered with only 1-2% oriented horizontally; black shales dominant with some dark reddish brown (2.5YR 3.4) and grayish red (2.5YR 4/2); some shales high in carbonates; few roots to a depth of 25" probably coming from locust trees in the vicinity; some carbolith present.

Notes: pH values

depth	pH
Surface	4.0
5"	4.2
15"	6.5
20"	6.0
25"	6.2
35"	6.5

The surface was thought to be an area of oxidation because of the low pH. This spoil was well mixed with the bad portion put back on top. The surface was white which was probably caused by an accumulation of salts, also causing a surface crust to be formed. A level was used to determine the slope of several coarse fragments:

1. 14% (7°) looked nearly level
2. 66% (33-1/3°)
3. 45% (26°)

APPENDIX D

Minesoil Profile Description

Site 3-2

DATE: July 24, 1971

LOCATION: Site is located in Preston County 1/2 mile south and 1/8 mile east of Beech Run Church. Bakerstown coal.

DESCRIBED AND SAMPLED BY: Sencindiver

VEGETATION: Black locust, poverty grass, colts foot, wild strawberry, deertongue grass. 20-25 year old spoil.

Horizons:

1	0-5"	--Brownish black (10YR 3/2); few, distinct bright yellowish brown (10YR 6/8) mottles; fine weak granular structure; friable; 40% shale coarse gragments; many roots; pH 4.5; few black concretions; clear boundary.
2	5-10"	--Dull yellow orange (10YR 7/4) and bright yellowish brown (10YR 7/6) and other variegated colors; massive; firm; 40% shale coarse gragments; many roots; many, prominent high chroma mottles; few brownish gray (10YR 6/1) concretions; clear boundary.
3	10-37"	--Dull yellowish brown (10YR 4/3); massive; firm 50% shale coarse fragments in disordered orientation; shales of various colors - dark reddish brown (2.6YR 3/2 and 3/3), black (10YR 2/1), grayish olive (5Y 3/3); bright yellowish brown (10YR 7/6); common roots; pH at 35" was 6.0.
4	37-57"+	--Yellowish brown (10YR 5/6), grayish yellow brown (10YR 6/2), and bright brown (7.5YR 5/8), silty clay loam to silty clay; massive; firm; 2-5% coarse fragments; black concretions present; very few roots.

APPENDIX D

Minesoil Profile Description

Site: 4-1

DATE: July 20, 1971

LOCATION: Site is in Monongalia County, 1 1/2 miles due east on Rt. 119 and Canyon Road intersection, on Mary Judy Farm. Pittsburgh coal.

SAMPLED AND DESCRIBED BY: Sencindiver, Smith

VEGETATION: Poverty grass, prostrate cinquefoil, tulip poplar and other trees. Approximately 10 years old.

Horizons:

1 0-2" —Clay loam; weak granular structure; friable; many roots; few fragments of black shale and sandstone; clear, wavy boundary.

2 2-7" —Strong brown (7.5YR 5/8) and dark brown (10YR 4/3) clay loam; massive; firm; many roots; many prominent low chroma mottles; 20% dark red (2.5YR 3/6) and carbolithic material.

3. 7-36"+ —Yellowish brown (10YR 5/4) and brownish yellow (10YR 6/6) clay loam with pockets of light gray (10YR 6/1 and 10YR 7/1) silty clay; firm; few roots; massive; many prominent gray (10YR 5/1) mottles; 20-25% strong brown (7.5 YR 5/8) and reddish yellow (7.5YR 6/8) sandstone fragments and 20-25% black (10YR 2.5/1) carbolithic material.

Notes: Coarse fragments dominantly disordered, and randomly oriented. Enough sandstone to be Typic (mixed).

depth	pH
Surface	4.5
7"	4.5
15"	4.5
25"	4.5
34"	4.5

APPENDIX D

Minesoil Profile Description

Site: 5-1

DATE: May 24, 1972

LOCATION: Site is located in Preston County, 2 miles south and 1 mile east of State Rt. 92 and Birds Creek Road intersection. Upper Freeport Coal.

DESCRIBED AND SAMPLED BY: Sencindiver and Ammons.

VEGETATION: Only regraded approximately 90 days. No vegetation.

Horizons:

1 0-8" --Variegated yellowish brown (10YR 5/4), yellow (10YR 7/6), brownish yellow (10YR 6/8) sandy clay loam; very friable; massive; 5% coal fragments; 65% dark reddish brown (5YR 3/4) light gray (N 7/0 and N 6/0) and brownish yellow (10YR 6/8) sandstone fragments; 10% of sandstone fragments > 3" diameter; sandstone fragments are disordered. Clear irregular boundary.

2 8-30"+ --Variegated colors same as above horizon; sandy clay loam; massive; 75-85% sandstone fragments with 60% of these 3" diameter; approximately 50% of sandstone fragments are layered horizontally; no coal fragments.

Notes: 25% carbolith on the surface in different spots. Gray and red sandstone on the surface with the gray sandstone being acid. Vegetation around the site is Black birch, red maple, fire cherry, wild grape, white oak, dogwood, service berry, and sumac.

depth	pH
3"	4.0
17"	5.0

APPENDIX D

Minesoil Profile Description

Site: 6-1

DATE: September 22, 1972

LOCATION: Site is located in Monongalia County, 1/2 mile west of Fort Martin School. Sewickley coal.

DESCRIBED AND SAMPLED BY: Sencindiver, Sturm, Akers.

VEGETATION: Wheat, pilewort, foxtail, ragweed. 2-3 years old.

SLOPE: 19%.

Horizons:

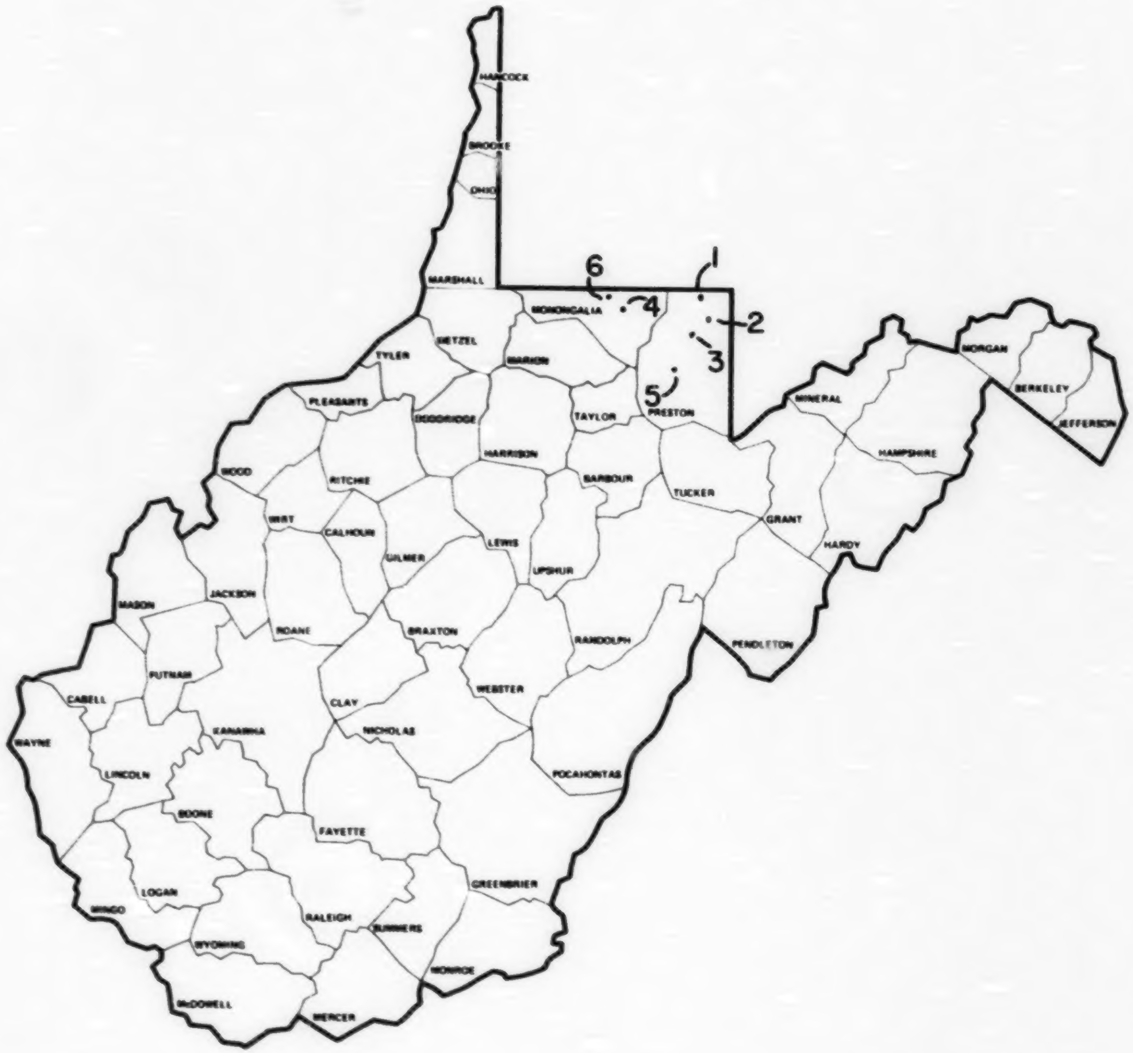
1	0-2 1/2"	—Yellowish brown (10YR 5/4) and brown (10YR 5/3) silty clay loam; weak granular structure with some pockets massive; friable to very friable; many fine roots; 40-45% yellowish brown (10YR 5/6) and grayish brown (2.5 Y 5/2) shale fragments and < 5% sandstone fragments; pH 7.7; clear wavy boundary.
2	2 1/2-11"	--Yellowish brown (10YR 5/4) and brown (10YR 5/3) silty clay loam; massive; firm, common fine roots; common distinct yellowish brown (10YR 5/8) and brownish yellow (10YR 6/8) mottles and few faint light brownish gray (2.5 Y 6/2) mottles; 50% very dary gray (N 3/0), gray (N 5/0) and olive yellow (2.5 Y 6/6) shale fragments; 5% sandstone fragments; are 3" in diameter; pH 7.3 in one spot and 4.6 in another spot; clear wavy boundary.
3	11-26"	—50% brownish yellow (10YR 6/8) and yellowish red (5YR 4/6) clay and 50% brownish yellow (10 YR 6/6) silty clay loam; massive, firm; few fine roots; common distinct yellowish brown (10YR 5/4), and strong brown (7.5YR 5/8) mottles and few faint gray (5 Y 6/1) mottles; 50% gray (N 5/0) and very dark gray (N 3/0) shale fragments with 5% 3" diameter; 5% sandstone and 5% limestone fragments;

pH 6.5 of reddish clay, pH 6.9 of yellowish brown material. pH 6.2 of mixed colors; gradual irregular boundary.

4 26-36"+ —Light yellowish brown (10YR 6/4) and yellowish brown (10YR 5/4) silty clay loam with pockets of clay; massive; firm; few fine roots; many prominent yellowish brown (10YR 5/8), light yellowish brown (2.5 Y 6/2) and strong brown (7.5YR 5/6) mottles; 50% very dark gray (N 3/0) and dark gray (N 4/0) shales with 5-10% > 3" diameter; 5% sandstone and < 5% limestone fragments; pH 5.1 of clay pocket, pH 2.0 of dark gray shale, pH 7.0 in mixed color material.

Notes: Surface pH 7.7
Localized spots of free carbonates on the surface. 35-50% coarse fragments showing on surface with 15-20% of these sandstone and 1-2% limestone. Coarse fragments disordered throughout profile. Pockets of original A_1 material found at about 30". Several limestone fragments found throughout profile. Greenish gray (5 GY 5/1) and pale olive (5 Y 6/4) shales found on the surface.

APPENDIX D SITE MAP



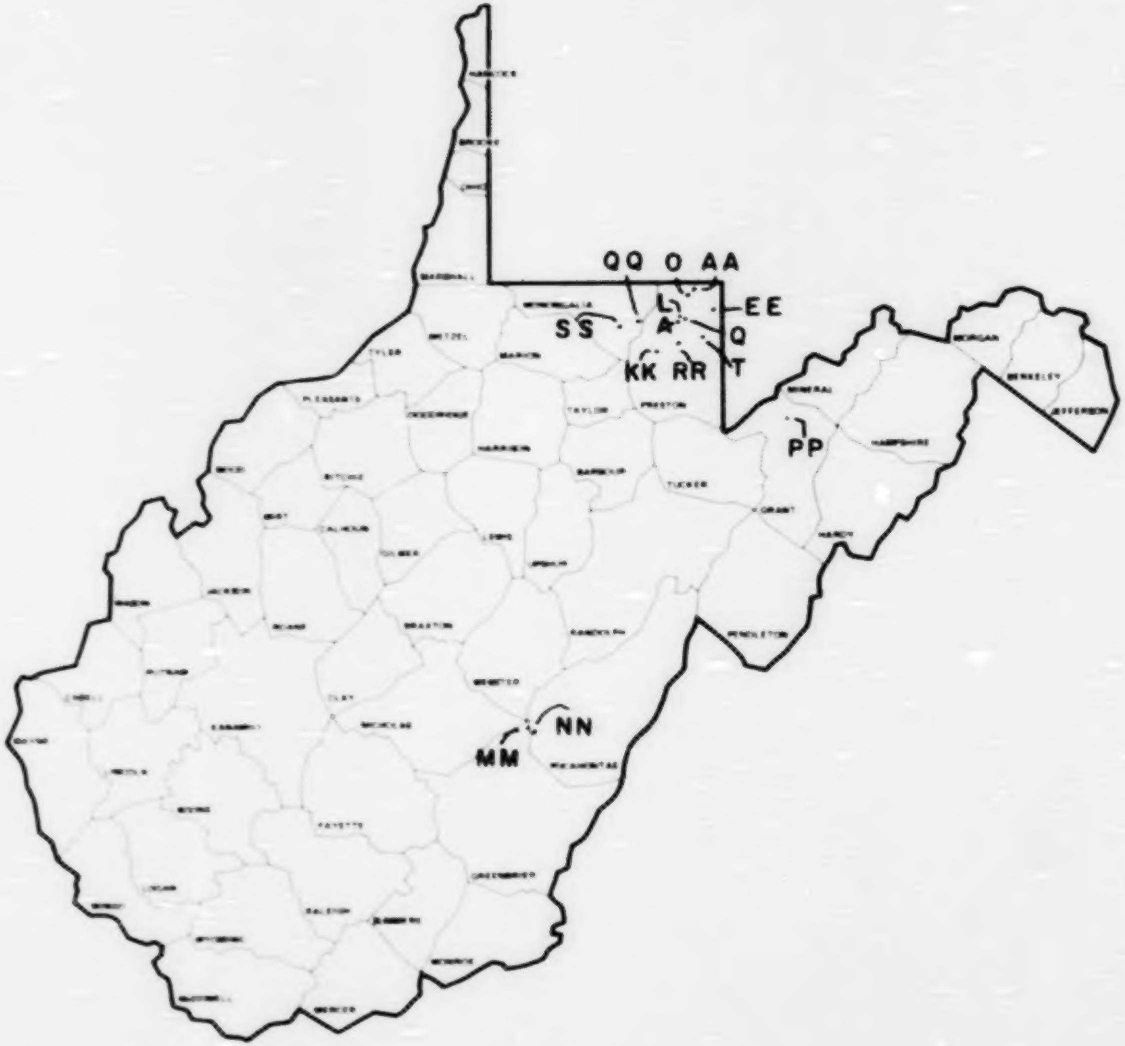
APPENDIX E

Locations of field study sites not directly plotted on cross sections in Section IV.

Site	Latitude Longitude Surf. Elev.	Coal Seam	Detail of Site Location
PP	39.26284°N 79.20710°W 2760'	Elk Lick	About one and one-half miles southeast of Mt. Storm, Grant County.
Q	39.56517°N 79.62512°W 2020'	Bakerstown	Three-fourths mile southeast of Valley Point, Preston County.
T	39.50174°N 79.61696°W 1790'	Bakerstown	One and one-half miles northeast of Albright, Preston County.
A	39.56496°N 79.64700°W 1860'	Upper Freeport	One-half mile west of Valley Point, Preston County.
L	39.57781°N 79.65204°W 1970'	Upper Freeport	About one-half mile north of Site A.
AA	39.70181°N 79.59095°W 1980'	Upper Freeport	Three miles northeast of Brandonville, Preston County.
KK	39.40402°N 79.78932°W 1820'	Upper Freeport	Three and one-half miles northeast of Newburg, Preston County.
QQ	39.58840°N 79.89653°W 1670	Upper Freeport	About one and one-half miles south of Dellslow, Monongalia County.

Site	Latitude Longitude Surf. Elev.	Coal Seam	Detail of Site Location
RR	39.47772°N 79.74409°W 2130'	Upper Freeport	One mile south of Manown, Preston County.
SS	39.51416°N 79.94556°W 1660'	Upper Freeport	About two and one-half miles west of Gum Spring, Monongalia County.
O	39.69282°N 79.57849°W 1930'	Lower Kittanning	Two and one-half miles northeast of Brandonville, Preston County.
EE	39.65555°N 79.52010°W 2080'	Lower Kittanning	One-half mile east of Hazelton, Preston County.
MM	38.16170°N 80.37627°W 4225'	Sewell	Five miles northwest of Lobelia, Pocahontas County.
NN	38.15512°N 80.36376°W 4200'	Sewell	Four miles northwest of Lobelia, Pocahontas County.

APPENDIX E SITE MAP



APPENDIX F

Site locations for sandstones included in petrographic study of sandstone weathering.

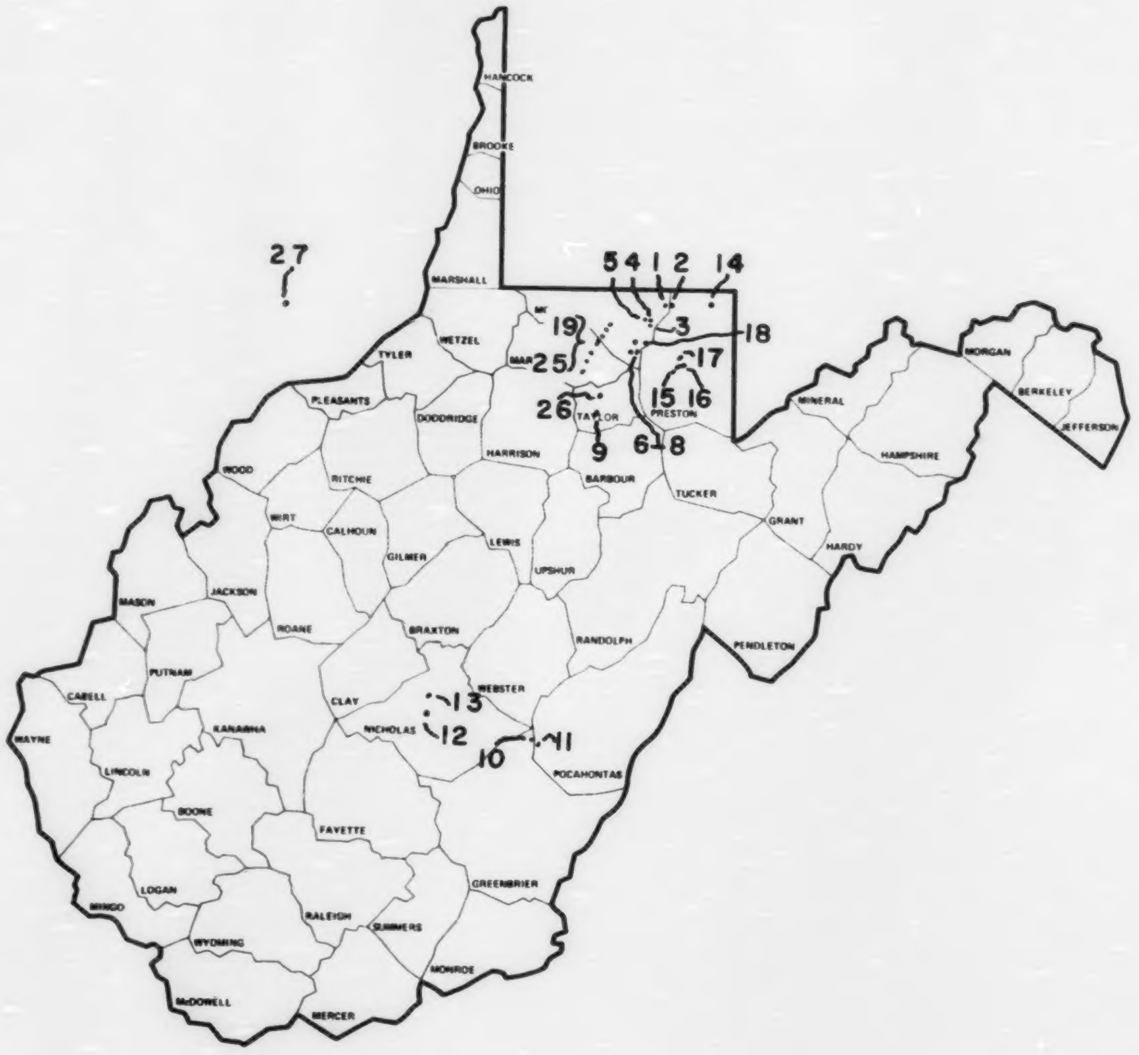
Site	Latitude Longitude Elev. (ft.)	Sandstone	Detail of Site Location
1	39.65586°N 79.77215°W 2260'	Connoquenessing	Roadcut along Corridor E 0.5 mi. East of Coopers Rock Entrance, Preston County, W.Va.
2	39.65464°N 79.76543°W 2140'	Connoquenessing	Roadcut along Corridor E 2 mi. East of Coopers Rock Entrance, Preston County, W.Va.
3	39.56435°N 79.76543°W 2090'	Connoquenessing	2.5 mi. West of Masontown (Deckers Creek Sandstone Quarry) Monongalia County, W.Va.
4	39.55967°N 79.84392°W 1940'	Connoquenessing	Quarry 2.5 mi. West of Masontown, Preston County, W.Va.
5	39.55914°N 79.85434°W 2100'	Connoquenessing	Quarry 3 mi. West of Masontown, Monongalia County, W.Va.
6	39.50114°N 79.91544°W 1950'	Homewood	Deerfield Sand Quarry 10 mi. South of Morgantown on Rt. 119, Monongalia County, W.Va.
7	39.57308°N 79.88750°W 1880'	Homewood	Quarry 0.5 mi. West of Browns Chapel, Monongalia County, W.Va.
8	39.57886°N 79.87865°W 2100'	Homewood	Quarry 0.5 mi. North of Browns Chapel, Monongalia County, W.Va.

Site	Latitude Longitude Elev. (ft.)	Sandstone	Detail of Site Location
9	39.38732°N 80.08602°W 970'	Sandstone in Pottsville series	Valley Falls State Park South of Grafton, Marion County, W.Va.
10	38.15512°N 80.37628°W 4225'	Guyandot	Surface Mine 5 mi. West of Lobelia, Pocahontas County, W.Va.
11	38.15512°N 80.36360°W 4200'	Guyandot	Surface Mine 4 mi. West of Lobelia, Pocahontas County, W.Va.
12	38.31256°N 80.84855°W 1880'	Monitor	Surface Mine 2 mi. North of Summersville, Nicholas County, W.Va.
13	38.43394°N 80.78395°W 2240'	Allegheny	Outcrop along Rt. 19 10 mi. North of Summersville, Nicholas County, W.Va.
14	39.69406°N 79.57373°W 1920'	Allegheny Sandstone overlying Lower Kittanning Coal	Surface Mine 3 mi. NE of Brandonville, Preston County, W.Va.
15	39.40529°N 79.72815°W 1780'	Mahoning	Surface Mine 2 mi. NE of Tunnelton, Preston County, W.Va.
16	39.45843°N 79.72174°W 1910'	Mahoning	Road Outcrop 2.5 mi. NE of Tunnelton, Preston County, W.Va.
17	39.44965°N 79.71473°W 2000'	Mahoning	Road Outcrop 0.2 mi. East of Irona, Preston County W.Va.

Site	Latitude Longitude Elev. (ft.)	Sandstone	Detail of Site Location
18	39.55646°N 79.87518°W 2100'	Mahoning	Surface Mine 2 mi. West of Masontown, Preston County, W.Va.
19	39.40353°N 80.04607°W 1430'	Mahoning	Road Outcrop 2 mi. South of Quiet Dell School, Marion County, W.Va.
20	39.59126°N 79.98156°W 940'	Buffalo	Quarry NW of Uffington across Monongahela River, Monongalia County, W.Va.
21	39.52128°N 80.02269°W 1390'	Sandstone in Conemaugh Series	Roadcut along I-79 2.1 mi. North of Weigh Station between Fairmont and Morgantown, Monongalia County, W.Va.
22	39.47753°N 80.10488°W 1110'	Sandstone in Conemaugh Series	Roadcut along I-79 1 mi. North of Downtown Fairmont Exit, Marion County, W.Va.
23	39.46850°N 80.13243°W 1200'	Sandstone in Conemaugh Series	Roadcut along I-79, 2 mi. North of Pleasant Valley Exit, Marion County, W.Va.
24	39.46294°N 80.13799°W 1040'	Sandstone in Conemaugh Series	Roadcut along I-79 0.5 mi. North of Pleasant Valley Exit, Marion County, W.Va.
25	39.55671°N 79.98422°W 1150'	Sandstone in Conemaugh Series	Roadcut along I-79 1.5 mi. North of Goshen Road Exit, Monongalia County, W.Va.

Site	Latitude Longitude Elev. (ft.)	Sandstone	Detail of Site Location
26	39.30978°N 80.05024°W 1030'	Sandstone in Conemaugh Series	Road Outcrop at Intersection of Rt. 119 & 250 South of Grafton Taylor County, W.Va.
27	39.66732°N 81.46079°W 1020'	Sandstone in Monongahela Series	Surface Mine 1 mi. Northeast of Dexter City, Noble County, Ohio.

APPENDIX F SITE MAP



APPENDIX G

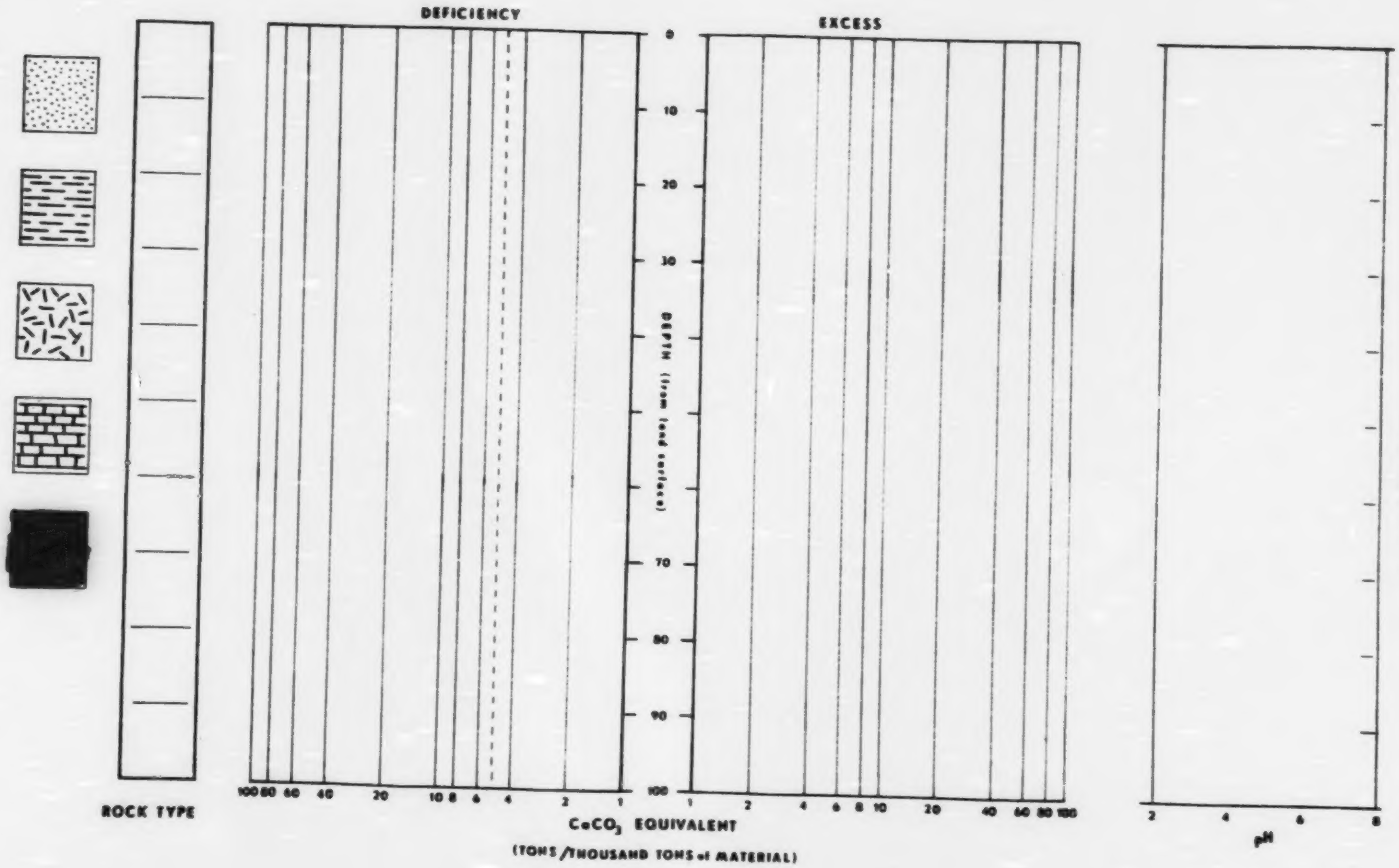


FIGURE 50. FORM SUGGESTED FOR PRESENTATION OF DATA ILLUSTRATING TOXIC OR POTENTIALLY TOXIC MATERIAL IN A SECTION OF COAL OVERBURDEN.